MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXIII. *January* 10, 1873. No. 3.

PROFESSOR CAYLEY, F.R.S., President, in the Chair

John Tebbutt, Esq., Windsor, N.S. Wales,
George Forbes, Esq., Anderson University, Glasgow,
Charles Carpmael, Esq., St. John's College, Cambridge,
W. S. Macdonnell, Esq., Sydney, N.S. Wales; and
Edwin Lawrence, 94 Westbourne Terrace,

were balloted for and duly elected Fellows of the Society.

A Proposed Double Altazimuth.

By R. C. Carrington, F.R.S.

It must have occurred to many members of the Royal Astronomical Society to ask themselves the question,—What is likely to be the next movement ahead in the construction of a first-class meridional instrument? I propose to suggest one such solution, with the view of possibly drawing out a criticism and discussing the primary principles which are to be kept to; and I do so without consideration of the cost, except that of two kinds of instrument the most efficient one shall have the choice. English artists have so long been the foremost constructors of such instruments that I should be sorry to see them surpassed by the Americans, French, Germans, or Russians. In the last generation seconds of arc were the battle-field of astronomers; now tenths of seconds have taken their place, shortly we may look for hundredths and thousandths.

My proposal is for a *Double Altazimuth*, capable of reversion in all its parts, with a perfectly open mirror or object-glass, without tube, and with reversible and exchangeable eyepieces, each carrying a setting circle of 2 feet diameter, and each floating hori-

zontally. For the Equatoreal has one main defect, the contraction of the support of the polar end of the axis in excess of the lower end as temperature decreases, a defect which is common to all constructed at Konigsberg, Poulkova, Harvard, U.S., Greenwich, and elsewhere.

'Consider first, that great
Or bright infers not excellence.'—MILTON.

It will be well to begin by referring to fig. 1, in which I have drawn a parabola on a large scale. I take the following proportions:—O F is 100 feet; consequently the points A and B are each 100 feet from F the focus. The tangents O A and O B, as is well known, intersect each other, at O, at right angles. The equation to the parabola, referred to these tangents as rectangular co-ordinates, is

$$x^2 - 2xy + y^2 - 200\sqrt{2}(x + y) + 20000 = 0.$$

and gives on solution the following corresponding values of x and y:—

$x = 100\sqrt{2} - 3$ feet	$y = 0{\cdot}1932$ inch
$100\sqrt{2} - 2$,,	$0{\cdot}0856$,,
$100\sqrt{2} - 1$,,	$0{\cdot}0216$,,
$100\sqrt{2}$	$0{\cdot}0000$,,
$100\sqrt{2} + 1$,,	$0{\cdot}0204$,,
$100\sqrt{2} + 2$,,	$0{\cdot}0830$,,
$100\sqrt{2} + 3$,,	$0{\cdot}1884$,,

Next compute the subtenses of the radii of the circles in which the parabola will revolve round the axis in becoming a paraboloid of revolution at the points -2, -1, 0, $+1$, $+2$, or take,

$98^f{\cdot}5158$, $99^f{\cdot}2929$, 100^f, $100^f{\cdot}7071$, $101^f{\cdot}4142$

and we get

Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
		0·0025	0·0024	0·0023		
	0·0006	0·0006	0·0006	0·0006	0·0006	
0·0000	0·0000	0·0000	0·0000	0·0000	0·0000	0·0000
	0·0006	0·0006	0·0006	0·0006	0·0006	
		0·0025	0·0024	0·0023		

If now we add together these numbers, we shall have a measure of the curvature of each point of our mirror, expressed as subtenses from the plane at the tangent at point A or B, at 1 foot apart every way,—namely,

Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
		0·0241	0·0024	0·0227		
	0·0862	0·0222	0·0006	0·0210	0·0836	
0·1932	0·0856	0·0216	0·0000	0·0204	0·0830	0·1834
	0·0862	0·0222	0·0006	0·0210	0·0836	
		0·0241	0·0024	0·0227		

It remains to be seen whether any artist can construct an ellipse of 6 feet by 4, on such a curvature, parabolic in the direction of the major axis and circular in the direction of the minor axis. The curve is a very flat one. The ratio of aperture to focal height will be $\frac{4}{100}$ or $\frac{1}{25}$. A list of these ratios may be seen in Professor Powell's paper in the *Monthly Notice* of March 13, 1857, taking into account the errata mentioned at page 222, and it will be seen that for the Northumberland Equatoreal at Cambridge $\frac{A}{F} = \frac{1}{20{\cdot}3}$. My proportion is long, but not extraordinary. Having defined the mirrors I would get, I now proceed to show how I would place them, and refer to figs. 2 and 3, where it will be seen that I propose to place them back to back, at an angle of 90°, with their two foci turned outwards at a distance apart of 205 feet, or thereabouts. Observers are supposed placed at A and B, looking through two eyepieces *floating*, as I have before said. Now turn to fig. 4, and notice the collimator in the centre, which consists of two object-glasses, 8 inches in diameter, viewing each other. These must be of 103 feet focal length each, or thereabouts; and their object is, by turning the instrument round, as in fig. 4, to let them be seen through at the same time, and to inspect the line of level till it is placed perfectly and zero. The eye-pieces are then to be clamped in level. By turning the instrument round to the polar star, observe, with A eye-piece on A mirror, and B eye-piece on B mirror, a complete set of passages of the polar star; and likewise, with A eye-piece on B mirror, and B eye-piece on A mirror, the same, and you have the values of wires known. Next, with A eye-piece on A mirror, and B eye-piece on B, take a transit of one wire, then turn A to B and B to A, and take another. This comparison gives you the collimation error doubled. Then, again, compare with a south star and you determine the azimuth.

Of course I do not mean this simply. The observer would be more likely to take 4 wires in one position and 3 in the other, alternately. To move the mirror in azimuth and altitude, and read off the microscopes, I suppose two other observers are required, thus requiring four persons at a shift. I reckon three hours at a shift, and four observers at each shift. Thus for three shifts I should provide twelve men, and be ready at all times, day and night, when the sky is clear. Fig. 6 gives the position of the instrument as seen for observation, the spaces painted blue being the mirror of one side, and those painted pink the altitude circle with its pair of micrometers. There are two altitude circles and two pairs of micrometers, as shown in figure 5. The azimuth circle is seen below, painted yellow. There is also a rough azimuth circle for the purpose of setting, which might be graduated by comparison with the fixed circle read by six microscopes.

Of course, it will be said, "What is the use of proposing schemes which can never be accomplished?" To this supposed question I might answer, "What is the use of sitting still and

never imagining anything beyond what is put before you ?" But I will endeavour to meet the objection by pointing out that whatever you do, it is essential to bear in mind that as soon as you pass the limit of size of a revolving object-glass, as is pretty nearly done already (for I reckon that no one will propose again to mount a larger object-glass than 12 inches in diameter, as is done in the transit-circle at Greenwich, for example), you come upon the question, "What is the simplest form of instrument with a fixed object-glass ?" And I say, till I am corrected, that at the bottom of all lies the fact that you must have a mirror capable of being placed at all angles to the horizon. It depends on whether you prefer metal or glass. For glass you have three persons only to apply to,—Mr. Chance of Birmingham, M. Feil of Paris, and a Belgian manufacturer. The cost, which I put out of account, would be enormous. Taking my prism of 6 inches in the side, which cost £60, and reckoning the cost at the cube of the dimensions, a pair of prisms of guaranteed quality would come to £61,440, besides the cost of a pair of object-glasses.* M. Feil's price would be lower than this, if he would undertake the size at all. But as this is practicable, let us consider it, only bearing in mind that you have six surfaces to contend with instead of one in the mirror. The construction will be as follows :— First, I erect a steel axis, 18 feet high by 2 feet in diameter, with a head of 8 feet diameter by 1 foot 4 inches deep, on to which I attach a platform of boiler-plate work, braced wherever necessary, of the size of 20 feet by 20 feet, and 2 feet deep, attached by 12 enormous screws to the head of the axis. This, I imagine, will carry anything put upon it, and that an observer standing on it would not affect it the slightest. Above this come two hydraulic presses, shown in the centre, carrying the counterpoises, each of four wheels, 4 feet in diameter, the position and action of which a comparison of the diagrams will show. Then the Y's, which I no longer make in the form of Y or V, but I will say the guides, each adjustable, and reckoned to bear strains of 20 lbs. each, the counterpoises taking the main actual strains. Then I suppose constructed a cylinder, of boiler-plating, braced or solid as may be thought best, of the external dimensions of 17 feet in length and 6 feet 8 inches in diameter, internal diameter 4 feet, in which I suppose the prisms and the object-glasses placed as drawn.

These dimensions, though necessary to be given, are, I am aware, only a poulterer's description of a phœnix, as Sheridan once said, and it may be well to point out, that at each end of the 17-feet tube I place a revolving circle in altitude, of the unavoidable size of 9 feet diameter, and in the centre two other circles, one for clamping and the other for setting by with a

* This is incorrect. The contract was for 7 inches, of which one was to be ground away. In the same way take 49 inches as the contract, and you have £120 × 7 × 7 × 7 = £41,160.

tangent screw (not drawn). The azimuth-circle I make of the same size, 9 feet diameter, read by six microscopes. There is no advantage gained in so large a circle, but rather the contrary. I hold that a circle of 30 inches, or 3 feet without spokes read by powerful microscopes, 6 feet in length, is capable of doing better work than one of 9 feet, subject to the same variations of temperature. I have drawn plans for four microscopes in altitude, two to each circle, but they may be replaced by six to each circle if required, and no objection is made to lengthening the platform.

It will be asked of what I propose to make the pivots,—I reply, of steel, shrunk on to the boiler-tube, and then turned down on dead centres. They will be 7 feet in diameter. The screws of the altitude circle appear to be turned the same way, but they work in opposite directions. My own are so placed.

The drawings are given to the scale of $\frac{1}{100}$ for the parabola and figs. 2 and 3, and $\frac{1}{16}$ for all the rest, in the originals; but in the lithographs are reduced one sixth again, so that figs. 1, 2, and 3 are in the proportion of $\frac{1}{600}$, and the others $\frac{1}{96}$.

It may be pointed out that by supposing a hollowed tube of 17 feet length, the mirrors of the first design can be supported throughout, resting on the back.

I have only to add, that I recommend that the webs of the micrometers be of parallel lines, of the same strength as the division which is seen between them; and that guide-lines should be engraved on the circles to indicate that the point viewed is the centre, and not any other part of the division. My circles at Churt are so divided.

On Mr. Carrington's Note of the Rate of a Clock going in a partial Vacuum. By Rev. T. R. Robinson, D.D.

I have read with much interest Mr. Carrington's account of the rate of his clock in a partial vacuum, given in the last Number of the *Monthly Notices;* for, although the barometric compensation which I applied to the Armagh transit-clock is completely successful, yet the adjustment of it requires too much time by calculation for that method to be generally adopted; while there is no great difficulty in establishing a clock in a rarefied medium of invariable density.

Mr. Carrington's chief impediment seems to have been the fracture of the plate-glass enclosing the front of his clock-case. This would not have occurred if he had constructed the case on the plan invented by Sir Edward Sabine, and modified by the late Mr. Francis Baily, in their researches on the reduction of a pendulum's rate to a vacuum (*Phil. Trans.* 1829 and 1832.) In their apparatus large flat surfaces of glass are avoided; and the pressure is sustained by convex ones, on the principle of the arch. Many years ago the late Sir James South made such an

apparatus, in which he tried several of his clocks for weeks together, in a vacuum as complete as an ordinary air-pump can produce. It consisted of a pear-shaped copper vessel about 30 inches diameter on a level with the bob of the pendulum ; a strong ground brass plate was soldered to its top, on which the clock was fixed ; and this was covered by a bell glass with a ground edge, like the receiver of an air-pump. A narrow slip of plate-glass below permitted the reading of the arc of vibration, but as this had a very small surface there was no danger of its fracture.*

I wish to direct the attention of astronomers to page 227 of Sir Edward Sabine's memoir, already referred to, where he describes the retardation in an atmosphere of dry hydrogen at the normal pressure. It is such as would occur in air at a pressure of 5·70 inches. A clock in such an atmosphere would require far less maintaining power, and would therefore work with less friction ; while the oil applied to its moving parts would not be liable to chemical change from absorption of oxygen. There also would be much less danger of any alteration of the medium by leakage than in the case of a partial vacuum. Mr. Carrington's coefficient of barometric retardation is higher than what I found for the Armagh clock's mercurial pendulum = 0·37, or Mr. Baily's result for a detached one (*Phil. Trans.* 1832, p. 436) = 0·41.

The difference probably depends on the arc of vibration. This varied but little during my observations, and was allowed for in Mr. Baily's.

It may interest some readers of the *Monthly Notices* to know that the first application of a vacuum to horology was made about sixty years ago by Manton, the celebrated gunsmith, who submitted to the Admiralty a chronometer enclosed in an exhausted receiver, and wound through a stuffing-box. It was tried during a voyage of two years by the late Admiral Beaufort, who reported very favourably of its performance : but the Admiralty took no further action in the matter, and the affair seems to have been forgotten.

Observatory, Armagh,
December 20, 1872.

On a Compensation for the Barometric Errors of Clocks.

By E. B. Denison, LL.D., Q.C.

Mr. Carrington's paper in the November *Monthly Notices*, on the retardation of a pendulum by increased density of air, suggests the expediency of providing a compensation for it, which is so easy that I wonder it has not been done before. It seems indeed from Dr. Robinson's paper just now read, that it has been done in some way ; but as he speaks of the difficulty of

* It is to be regretted that these experiments have not been published ; they form part of an extensive investigation into the various circumstances which influence the going of a clock, which was conducted with great care.

calculating the adjustments for it, I infer that it was different from that which I propose, as that can be very easily calculated and applied to existing pendulums.

But it is necessary to observe that the amount of this error varies largely between clocks of nominally the same kind, and much more between those of different kinds; so much that it cannot safely be assumed beforehand for any clock, but must be determined by experiment. The subject was adverted to, but no experimental conclusion arrived at, by our first President, in an elaborate paper chiefly on Compensation for Temperature, in vol. i. of the *Memoirs;* and more fully and with more definite results by the late Mr. M. Bloxam in an equally elaborate paper on Escapements, in vol. xxii., followed by a posthumous supplement in vol. xxvii. He found this error to be as large as 1^s a day for 1 inch of barometer in a dead escapement clock of his own, while Mr. Carrington's result in a clock of that kind was $0^s{\cdot}72$. Bloxam's object was to show both mathematically and practically the inferiority of dead escapements to gravity ones, the contrary of which had long been supposed to be proved by the Astronomer Royal in vol. iii. of the *Cambridge Philosophical Transactions;* and he did show, among other things, that the barometric error ought to be and was much less in his own gravity escapement than in a dead one, and in fact only $0^s{\cdot}3$ (by which I mean per day and per inch of barometer throughout).

That escapement, though it was successful in his hands, was too delicate for common use, and I believe has never been copied with success. Hardy's gravity escapement has also quite gone out of use, partly for the same reason. I have not the means of ascertaining the amount of this error in any of my gravity escapement clocks, except as after-mentioned; nor in the detached escapement also described in my book on clocks. But Sir G. B. Airy tells me that the "barometric error of his normal sidereal clock with detached (chronometric) escapement, kept in a very even temperature, is $0^s{\cdot}3$," the same as Bloxam's.

It may save trouble to say shortly that the cause of the inferiority of dead escapements on this point (apart from others) is that the expression for their daily gain,—δ T, commonly called "rate," contains a term, which with the best possible construction is probably never less than $\frac{4\,\delta\alpha}{\alpha}$ seconds, and generally much more; while the corresponding term for the gravity escapement, or a detached one properly constructed, is insignificant for any such $\delta\alpha$ as can occur naturally. In the Westminster clock, with the double three-legged gravity escapement, it could not exceed $\cdot02^s$ (printed by mistake $\frac{1}{2}^s$, at p. 117 of my book, where the same general results as Bloxam's are arrived at by a shorter method), nor could it reach $\cdot05^s$ in any well made gravity escapement. It should be observed too, that the sign of this δ T is + in the gravity escapement where it is — in the dead, or is in the same direction as the circular error. In the detached it can be made so too, though it probably never is, by making more of the

impulse before than after zero. Moreover, any variation of arc alters the effect of friction on the dead escapement in a way that defies calculation, and is even opposite in different states of the clock. Increased density of air retards all clocks alike, by diminishing the specific gravity of the pendulum without diminishing the moment of inertia, and also by direct resistance to its motion, which reduces the arc and the velocity more in the descent of the pendulum than the ascent, in which a current has been established. On the other hand, this receives an uncertain amount of counteraction from the circular error, 10800 $\alpha\,\delta\,\alpha$ sec. — its reduction by the pendulum spring.

The exact amount of the barometric error however is not material for the present purpose. We need only find a compensation for it on some assumption of its amount and of the weight of the pendulum, and it will be easily modified for any other. The obvious mode of doing it is to attach a barometer to the pendulum which will raise enough mercury, from somewhere near the bottom to about 30 inches higher, to accelerate the pendulum as much as it is otherwise retarded by the increased pressure of air.

Let $M\,l$ be the weight × (simple) length of the pendulum, $2\,x$ the width of the tube, and r the absolute rise of the ☿ (both in inches); ϱ its specific gravity, which makes two cubic inches of ☿ very nearly 1 lb.; b the height of the lower surface above O the centre of oscillation, and d the depth of the upper surface below the pendulum top. Then reckoning M in lbs., and omitting higher powers of the very small quantities, we shall have,—

$$-\delta T = \frac{21600\,\pi\,r\,x^2}{M}\,\frac{d\,l + b^2 - b\,l - d^2}{l^2}\ \text{sec.}$$

Since d must be substantially $> b$ for this to keep its sign and be tolerably constant, there is not room to make the jar of ☿ for temperature compensation serve also for the barometer basin in a 39-inch pendulum, unless the rod is of glass, which might then be the tube. But that construction is not so desirable as it looks, since it would allow no adjustment or previous trial of that same pendulum, and would require a very wide jar to make the pendulum as heavy as is now agreed to be expedient. So we may confine our attention to steel pendulums, for which also cast iron jars are the best; and these must come 5 inches above C, as shown in my Appendix, in correction of a long-received miscalculation of Baily's in the above-mentioned paper; who strangely forgot the weight of the jar, and so misled some eminent clockmakers into erroneous notions about the compensation required for the pendulum spring. This mistake escaped Mr. Bloxam's detection, beyond finding by experience that the pendulum which had been made for him would not hold ☿ enough for complete compensation. Dead escapements have a counteracting but uncertain error, which had prevented this from being discovered long before. Hardy did calculate his compensation rightly, but Baily's authority had been accepted as conclusive.

The barometer tube then must either dip into the jar and come up again, which would prevent it from being turned for ordinary regulation, or else must bend over it and go down the right or left side to anywhere between the middle and the bottom, and return the same way. It had better be brought up to the rod again, and the two branches be joined there by heat, and tied to the rod by waxed thread, which will be better than any metal fastening.

A rise of 1 inch of barometer will then be an absolute rise in the long leg of $\frac{1}{2}$ inch ($= r$); and if we make $b = 0$ for simplicity, and $\therefore d = 9$ inches, and $M = 40$ lbs., and put $-\delta T = 0^s{\cdot}3$, the above equation will give $2x$ practically $= {\cdot}03$ inches. If the barometric error is 3 times as much, the width of the tube must be $\sqrt{3}$ times as much, or about ·05 inches, in either case a very small one. I suppose it would be filled with ☿ with both ends open, and then the top hermetically sealed. If the compensation is found to have been overdone, the tube has only to be raised, and if too little it may be lowered, if room has been left for it in the bend.

Longer pendulums are never used in astronomical clocks ; but they are in turret or public clocks, which now, with gravity escapements, sometimes exceed the accuracy of most astronomical clocks. If they are found to have this error in any sensible degree, it will be better to put an annular basin on the top of the bob, enclosing the rod, and wide enough to make the absolute rise of the ☿ in a straight tube sensibly = the relative rise. The most usual pendulum for good turret clocks of moderate size is $1\frac{1}{4}^s$ (61 inches), weighing about 200 lbs. with the compensation tubes of zinc and iron. There b may be 7 inches, and d about 2 feet, and that makes $2x = {\cdot}162$ inches if $-\delta T = {\cdot}3^s$ as before. Larger clocks have $1\frac{1}{2}^s$ pendulums (88 inches) of about 300 lbs., and here b may be 8 inches and $d = 50$ inches, and that happens to make $2x$ the same as for the lighter and shorter pendulum, because the barometer is in a more effective place. If the compensation is defective or excessive, it is better not to shift the basin, but to substitute a larger or a smaller tube. But this cannot happen if the clock has been properly tried before calculating the size for the tube, and it is made of the calculated size.

A few of the largest and best public clocks have 2^s (13 ft.) compensated pendulums with very heavy bobs. The Westminster pendulum weighs close upon 700 lbs. ; but on account of the great thickness of the zinc tube, which has to act as a column $10\frac{1}{2}$ feet long, the bob only reaches 2 inches above O. I find that with $b = 6$ inches, and $\therefore d = 10$ feet, the barometer tube should be just 0·3 inches wide if $-\delta T = 0^s{\cdot}3$.

But since making those calculations I have received from the Astronomer Royal the daily rate of the clock for 1872, except Sundays and a few other days; which reports itself to Greenwich daily, but is not controlled from thence by electrical connexion, as I find some persons erroneously suppose; and that throws a new light on the question as to this class of clocks. We must

reject for this purpose three evidently abnormal disturbances in the year, one of which reached 8^s in a week of thunderstorms and disturbances of rate, which I have known so produced in other clocks; and the others, of about 5^s each, came suddenly, I suppose from accidental shaking of the pendulum in putting on or taking off the small weight with which it is brought to time in a few days whenever it is above 2^s wrong, which is very seldom; for the daily variation never reached anything like that amount at any other time. Omitting these, the average daily variation was only $0^s{\cdot}4$, or $0^s{\cdot}2$ on each side of zero. Therefore the least barometric error above mentioned would form a very sensible part of the general errors of the clock. But, comparing the daily rates with the Registrar General's weekly reports of daily readings of the barometer, I cannot make out that any part of the clock-error is barometric. The application of any correction bearing a constant ratio (+ or −) to the variations of barometer rather increases than diminishes the average variation of the clock for two periods of 7 and 8 weeks, which I tried both in winter and summer; nor do I find any error of temperature compensation.

I can only account for this by supposing that the barometric error happens to be just compensated by the circular error which necessarily accompanies it. The arc α is about $2^\circ\ 30'$, which I intentionally made in 1860 more than is usual in astronomical clocks, though, I confess, without foreseeing this result, which seems specially to justify it. It is singular however, that the barometric error of Bloxam's clock was rather more with an arc of $115'$ than with $90'$, which I think much too small generally.

And if this is so at Westminster, it must be much the same in my own four-legged gravity escapement clock with 1^s pendulum, which is fully described in the Appendix to my book, as being better for small clocks than the double three-legs, which is now used in all the best large clocks. I have lately been observing mine, with a view to this question, by the sound of the first blow of the hour at Westminster, which has a special contrivance for making it fall exactly at the right time by the clock; and the error, if any, has been rather against the barometer in a time of very low pressure.

I do not at all conclude from these one or two instances that the barometric error may be generally assumed to be self-corrected in these gravity escapements; but the point is worth investigating by those who have the means of comparing such clocks directly with the stars.

I have no means of ascertaining the rate of my five-legged detached escapement, except over longish periods, and therefore not the barometric error, which never lasts long in one direction. All I can say is, that it has been going above seven years without being touched, except being put back about a minute a year for constant rate, and the arc has not yet visibly decreased, though

the train is not a particularly good one. I do not know how far the Greenwich clock on the same principle resembles it in construction; but from what I hear of that, and my own experience, I am inclined to think this the best of all escapements for astronomical clocks, which have only to keep themselves going with very little friction of a well made train, if the beat at only alternate seconds is not found inconvenient; and it does not answer for half-second pendulums. It is quite unfit for large clocks without a remontoire to equalise the force of the train; and I know by sad experience that the usual fate of those remontoires is to be removed by the first ignorant man who gets the care of the clock out of the hands of the maker.

Gravity escapements however have one clear advantage, even for astronomical clocks, in being able to bear any extra work involving friction which would be fatal to the accuracy of any direct impulse escapement, such as striking a small bell every minute, which I have seen done by one of them, or making electrical contacts, which affect the pendulum when done by it directly.

In comparing the performance of large and small clocks, it must be borne in mind, on one hand, that a long and heavy pendulum gives large ones a great advantage, because the expressions for all escapement errors contain $\frac{W h}{M l}$ ($W h$ being the daily moving force that reaches the pendulum), and $W h$ does not increase nearly so fast as $M l$. In the Westminster clock I know by trial that this fraction does not exceed $\frac{1}{80}$, even for that large arc, while it is certainly not less than $\frac{1}{30}$ in astronomical clocks with a smaller arc, after allowing a good deal for friction. On the other hand, the mean specific gravity of these iron and zinc pendulums is not above $\frac{2}{3}$ of a good mercurial one, which therefore has a better chance against the barometric error in both ways that the air affects it, and will also swing a larger arc always for the same impulse; and α^2 or α^3 appears in the denominator of all the variations, except the circular one. But most of all we must remember that the Westminster clock has to move something near two tons of hands and counterpoises and wheels at every beat of the pendulum, sometimes with and sometimes against the wind, on four dials of 22½ feet diameter, and through all the variations of friction of a train of cast iron wheels.

I do not profess to estimate the value of these differences, but I happen to have the means of comparing the weekly rate of Westminster with an old one of the Royal Exchange clock, by the same maker, with a compensated pendulum of the same length, and a jewelled dead escapement and a train remontoire, and dials only 9 feet wide, and cut gun-metal wheels, and every provision then known for making it "the best public clock in the world," as the Astronomer Royal rightly called it in 1845. Yet its average weekly variation for 1851 and 1852, after omitting all the appa-

rently abnormal disturbances, was very nearly 4^s, while that of Westminster, taken in the same way for 1872, was only 1^s. The Exchange rate was materially improved afterwards, by the substitution of a better remontoire, but I have no later record of it, and the clock passed into other hands in 1860; old Mr. Dent's foreman, who had the making and the care of it till then, and has since had that of Westminster, has often told me that it never approached Westminster in steadiness of rate. The average weekly variation of one of his best "regulators" for the same period as the Exchange clock was 2^s; and the rate of his 1851 Exhibition great clock, with pin-wheel dead escapement and the best train remontoire, was reported as being quite equal to that of the regulator fixed beside it. So that we may probably consider the rate of a rightly made large gravity escapement clock twice as good as that of any dead escapement one, large or small, and its barometric error much less, if not altogether neutralised.

On the Re-discovery of Biela's Comet. By M. Klinkerfues.

On comparing the brilliant meteoric shower of November 27th with those of other years, more especially with that of 1805, in which year, to the best of my knowledge, nothing of a similar character was observed, although the circumstances were particularly favourable, I was led to the assumption that in this instance we were in the closest proximity to Biela's Comet. A simple geometric consideration suffices to show that under these circumstances the comet must remain almost stationary in the neighbourhood of the radiant of convergence for a few days immediately following the occurrence of the meteoric shower, and further that there was even a hope of finding the comet itself, provided the intelligence could be at once transmitted to an observatory sufficiently far south. The paths of 80 meteors laid down by our Castellan, Mr. Heidorn, enabled me to determine the radiant point of divergence (R.A $= 26°$; Dec. $= +37°$) without bias.

On November 30th I sent the following telegram to Madras: "Biela touched Earth November 27th; search near *Theta Centauri*." This telegram reached Madras by way of Russia in one hour and thirty-five minutes.

Concerning the result Mr. Pogson, under date December 6th, writes to me as follows:

"Nov. 30th, 16^h, the time of comet rising here, I was at my post but hopelessly; clouds and rain gave me no chance. The next morning I had the same bad luck. But on a third trial, a brief blue break about $17\frac{1}{4}^h$ M.T., I found Biela immediately! Only four comparisons in successive minutes could be obtained, in strong morning twilight with an anonymous star; but direct motion of 2·5 seconds of time decided that I had got the comet all right. I noted it: 'Circular, bright, with a decided nucleus but no

tail, and about 45″ in diameter.' Next morning I got seven good comparisons with an anonymous star, showing a motion of 17ˢ·9* in twenty-eight minutes, and I also got two comparisons with a Madras star in our current catalogue, and with 7734 Taylor. My notes were: 'Circular, diameter 75″, bright nucleus, a faint but distinct tail, about 8′ in length and position angle estimated 280° from the comet.' I was too anxious to secure one good place of the one in hand to look for the other comet, and the fourth morning was cloudy and rainy. I used power 99 on the equatoreal of Troughton and Simms, eight inches in aperture, but could see the comet well in the finder. At a guess I should describe it as three times as bright as the cluster 80 *Messier*, in the field with R., S., and T. *Scorpii*. The two positions, so far (the first only approximate, but the second pretty trustworthy I think") are:—

	Madras Mean Time.			App. R.A.			App. P.D.		
	h	m	s	h	m	s	°	′	″
Dec. 2	17	33	21	14	7	27	124	46	0
3	17	25	17	14	22	2·9	125	4	28

Professor Klinkerfues adds:—

"At present I am engaged in preparations for the calculation of an ephemeris, as I am not without hopes that a few positions may be obtained even after the lapse of a few weeks. Of course the first thing to be done on receipt of the above letter was to assure myself that no provoking accident had led to the discovery of a comet altogether unconnected with that of Biela, in the place indicated. A provisional determination of the points of intersection of Mr. Pogson's *directions of observation* (*Beobachtungsrichtungen*) with the old orbit of 1852 gave

Mean Greenwich Time.	Distance from the Earth.	Distance from the Sun.
Dec. 2·5071	0·07301	0·92676
3·5015	0·08849	0·91248

the heliocentric co-ordinates of the two places referred to the equator (mean equinox of 1872·0) are

x	*y*	*z*
+ 0·26672	+ 0·82408	+ 0·32966
+ 0·24224	+ 0·81848	+ 0·32256

The chord joining the two points of intersection is 0·02619, and finally the Earth's co-ordinates for Nov. 27·3333 are

$$X = +0{\cdot}40856; \quad Y = +0{\cdot}82615; \quad Z = +0{\cdot}35848;$$

and the Earth's radius-vector, R. = 0·98618.

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* In Professor Klinkerfues's letter it is difficult to decide whether this is 17ˢ·9 or 17″·9; the former reading agrees well with the observations.—*Trans.*

"An examination of the foregoing figures leaves scarcely a doubt as to the identity of the comet observed by Mr. Pogson with one of the two heads of Biela's comet, and at the same time they show that an unusually small minimal distance from the Earth occurred in the course of November 27th."

Re-discovery of Biela's Comet. By Capt. Tupman.

Professor Klinkerfues was led to assign a place near θ *Centauri* as a natural consequence of his happy and bold idea that the comet itself had touched the Earth; and as it was found just as he expected, there was every reason to suppose that Pogson's two observations, combined with the supposed known position at the moment of contact, would give the real orbit.

I soon found that if the comet really grazed the Earth on the evening of Nov. 27th, it could not possibly have been observed in either of the positions given on December 2nd and 3rd, unless the inclination of the orbit be reduced to $7\frac{1}{2}^\circ$ (Query, $9\frac{1}{2}$.—Ed.) The radiant point of the meteoric shower of Nov. 27th points infallibly to an inclination of $12\frac{1}{2}^\circ$.

It may be said that after passing so exceedingly near to the Earth, the direction of motion would probably be much affected, and a new orbit be imposed upon the comet; but if so, the two observations *after* that event would determine approximately the form of a new orbit. As a matter of fact, the two observations are utterly irreconcilable with one another, on any such hypothesis.

The discrepancies, however, disappear if we suppose,—

1. That the meteor shower was produced by an outlying portion of the Comet, far detached from either nucleus on the side farthest from the Sun, and moving nearly on the same radius vector prolonged.

2. That the *primary* comet overtook the Earth in longitude about Nov. 27th, $3-4^h$ at a distance from the Sun less than that of the Earth by 0·032 of the latter's mean distance, and was discovered by Mr. Pogson on December 3rd.

3. That the *secondary* comet overtook the Earth in a similar manner ten or twelve hours earlier, and was that seen by Mr. Pogson on December 2nd.

In any case the comets are some twelve weeks "behind their time."*

* [It is easily shown that the meteor-flight traversed by the Earth on November 27 was far too scattered to be visible by reflected light. Moreover, a delay of Biela's Comet by twelve weeks could not be caused without a complete subversion of the orbit-element. It appears, however, that what Mr. Pogson saw was a meteoric aggregation travelling on the track of the comet; far behind, however; possibly double, as Capt. Tupman suggests; and certainly not coincident with the meteor-flight of November 27, which was probably on its outskirts.—R. A. P.]

Star Shower seen at Mauritius. By C. Meldrum, Esq.

A great shower of meteors was observed in this colony on the night of the 27th November last. I had not myself the good fortune to see it, but it was seen by several other persons who have obligingly communicated their observations.

At the Observatory it is customary to watch, as far as possible, for meteors during the whole of November, but on the night in question the sky was nearly overcast. At 9.15 P.M. we had a shower of rain, and at 9.30, when the last observation of the instruments and the weather was taken for the night, nine-tenths of the sky were overcast, and the weather was gloomy. Looking out about midnight from a window facing the north, I observed that the visible part of the heavens was still overcast, but remarked that the clouds were unusually luminous, as if the Moon in her first or last quarter were shining behind them. This struck me particularly, and I waited some minutes in expectation of seeing a break in the clouds.

On the following day, I received a telegram from the Hon. Edward Newton, Colonial Secretary, announcing that he and Mr. C. Bruce, Rector of the Royal College, had counted from their residence, twelve miles off, and nearly 900 feet above the level of the sea, 678 meteors between 9.30 P.M. and 12.55 A.M.; and soon afterwards I ascertained that some other members of our Meteorological Society, as well as several other gentlemen, had also observed the shower, all from the same part of the island.

In place of attempting to summarise the accounts which have reached me, I think it preferable to give them in full, in the order in which they were received.

(1.) *Mr. Newton and Mr. Bruce's Observations.*

"About 9.30 on the evening of November 27, we observed an unusual frequency of shooting-stars. At 9.35 we began to keep regular count. We continued our observations till 12.55, at which time the frequency had greatly diminished, as will be seen from the following statement of the numbers seen in the intervals of time noted:

From	9.35	to 10.35	786
	10.35	,, 11.35	1160
	11.35	,, 12.10	454
	12.10	,, 12.35	193
	12.35	,, 12.55	85
	Total		2678

"The approximate time of greatest intensity of the shower was from 11 to 11.30. About this time two meteors of extraordinary brilliancy were particularly noted—the first at 11.22, and the second at 11.44.

"The former of these started from the three stars in the tail of *Aries*, and the luminous orb vanished somewhat south of the Ecliptic. The train of this meteor was distinctly visible for four minutes. At the vanishing moment of the luminous point, it slowly wheeled from horizontal to vertical, and was seen for nearly two minutes vertical to the horizon.

"The latter, starting from a point at right angles to the three stars in the tail of *Aries* and the *Pleiades*, passed through the *Pleiades*, *Taurus*, and *Orion*, and vanished near *Sirius*. Its train was visible for more than a minute.

"Nearly all the meteors observed radiated from a point near *Aries*, nearly at right angles with the *Pleiades*, and shot either in the direction of the bright meteor of 11.44, or in a line through *Aries*, cutting the Ecliptic,—vanishing to southward.

"From 80 to 90 per cent of the meteors were followed by a soft broad train of light, visible for several seconds after the vanishing of the luminous point, of diameter at least equal to the luminous orb, and extending from 10 to 20 degrees. In the case of the two bright meteors above mentioned, the train of light extended over at least 40 degrees.

"During our observations, portions of the heavens were from time to time obscured by thin dark fleeting clouds, which at times obscured the starting and vanishing points.

"Between 10 and 11 we observed occasionally a pulsating coruscation, similar to the appearance of the Aurora Australis. Mr. Meldrum, however, informs us that the instruments at the Observatory gave no indication of a magnetic disturbance.

"In colour, the majority of meteors seemed to be equal in purity to the most colourless stars.

"Taking a point as above described as visible radiating point, the angle of the majority of meteors was about equal to that of the meteors, figured in Johnston's *Astronomical Atlas*, seen in November 1866. A few, however, shot with extreme velocity towards the North ; these had no trains of light. Other meteors shot parallel to the general direction close to the horizon. Although we discontinued our observations at 12.55, the shower was not over, and a few meteors were seen near the western horizon after this time.

"It must be observed that the point from which our observations were taken was obscured by trees in the direction of the western horizon.

"About the time of greatest intensity nine meteors were visible at the same moment.

"During the greater part of our observations, up to midnight, the radiation of three, four, or five meteors, was nearly synchronous.

"Towards the time of greatest intensity, one of the observers was absent for about 15 minutes, and it is probable that many meteors during this interval escaped observation."

(2.) *Observations by Lieut.-Colonel O'Brien, Inspector-General of Police, and Mr. A. Brown.*

"At about 10 o'clock last night (27th Nov.) our attention was drawn to the number of falling stars. Going outside and standing back to back, Mr. A. Brown and myself in a short time counted no less than 110. This continued till near 11 P.M.; when we went out again, and in 5 minutes counted 118. Some of these meteors were very bright, having tails like comets. Their course was generally longer than that of the others, and they seemed nearer to the Earth. The course of the shower was almost invariably from north to south, and more meteors were visible towards the Southern hemisphere than in other quarters."

(3.) *Observations by the Hon. Robert Stein and Mr. A. C. Macpherson.*

"On the 27th November, about 10.15 P.M., on looking towards the N.E., we noticed several meteors falling; the *Pleiades*, *Hyades*, and *Orion*, being at that time about 45° to 50° above the horizon.

"On observing carefully, we found the meteors in great numbers coming from due north, very much on a level with the stars above mentioned, and rather farther to the north of the *Pleiades* than the distance between the *Pleiades* and *Hyades*.

"They came, not from a point, but as it were along a broad belt crossing the Sun's path nearly at right angles, appearing at times in the north, but often also at the zenith and towards the southern horizon, passing as it were parallel, some from N.E. to S.E., some from north to south, and some from N.W. to S.W.

"The number of meteors was so great, and they appeared so irregularly, sometimes towards the north, sometimes overhead, sometimes right or left of the zenith, and sometimes towards the southern horizon, that we could not keep count of them; but from 10.15 to 10.30 they appeared to be falling at about the rate of one in every second, sometimes singly, and sometimes in twos or threes at a time. The more distant ones showed only bright luminous points, but the nearer every few minutes showed trains and sparks like a rocket, varying from 2° or 3° to 5° or 6° in length, and seldom reaching a length of 10°.

"Our view to the S.W. was partly closed, but on changing position, so as to get a view of that quarter, I found the meteors falling there too, but it appeared to me during the short time I looked in that direction, towards 11 o'clock, as if fewer were falling there than I had observed to the eastward of South."

(4.) *Observations by Mr. W. H. Marsh, Assistant Colonial Secretary.*

"I observed the shooting-stars at first at 9 o'clock. The sky was cloudy, but in spaces that were occasionally left clear, the meteors could be seen going from north to south. About half an hour later, the sky was quite clear.

"I counted 100 shooting-stars in less than 9 minutes. With the exception of one in *Andromeda*, which went in an easterly direction, they all went to the south. I continued observing till 10.30. The meteors were almost entirely confined to the western half of the sky, and by far the greater number were observed in *Aquarius* and in the neighbourhood of *Fomalhaut*. Most of them were very dim and small, but occasionally a bright one made its appearance. I observed a very bright one at about 10.15, which came from the direction of the zenith, and appeared to pass right through the star *Achernar*."

(5.) *Observations by Capt. Fry.*

"On the evening of the 27th November, my attention was drawn towards the heavens by seeing an immense number of stars of all magnitudes shooting towards the south from *Orion*, which was at the time about 30° above the eastern horizon, in a straight line through the zenith to about 40° above the western horizon, below which altitude clouds obscured the sky. The greater number seemed to move from the southern side of the above described line. They were all exceedingly bright, and varied in size from an ordinary meteor to *infinitely* small. The time was from 9 to 10.15 P.M., when clouds screened the view. I endeavoured to keep count, but could not, owing to the immense number, and the quickness of their movements. I am an old mariner and have often had opportunities of watching the heavens at night, but I never witnessed anything to compare to the sight on the night of the above date. On the 28th I made preparations to watch for a repetition of the spectacle, but not having seen more than is observed on an ordinary night, say four or five, I gave it up, and retired at 11 P.M."

(6.) *Observations by Capt. Gaston of Ship Penélope from Vahemar to Mauritius.*

"Le Mercredi, 27 Novembre, étant par une latitude de 19° 52′ Sud et 50° 25′ longitude Est, le temps était magnifique, mais calme. Vers $7\frac{1}{2}^{h}$ du soir une chose rare se montra au firmament; une quantité extraordinaire de météores parurent successivement, se formant dans le Nord, allant dans leur course vers le Sud-Est. Les uns donnaient une clarté très vive et d'autres ne laissaient qu'une légère traînée de feu ressemblant à des fusées; mais tous allaient avec une grande rapidité. Ce manège de petits météores dura jusque vers 2 heures du matin.

"Un autre fait non moins curieux s'était présenté dans la journée. Tous les marins connaissent l'Alcyon (ou hirondelle de mer), et tous savent que ces petits oiseaux se tiennent dans les eaux du navire, mais en petite quantité. Nous avons, pour ainsi dire, été assaillis par ces oiseaux, les uns voltigeant autour du

navire et les autres posés sur l'eau assez près les uns des autres ce qui ressemblait à une masse noire."

The above observations, with the exception of Captain Gaston's, were all taken within a circle of 3 miles in diameter, and at altitudes of 700 to 1000 feet.

There are, as might be expected, some discrepancies in the accounts given, but it appears that the meteors were seen in two streams, the one passing through *Aries*, *Pisces*, and *Aquarius*, nearly along the ecliptic, and the other through *Taurus*, across the ecliptic, and through *Orion* towards *Sirius*, while others passed the zenith from north to south.

The radiant point would appear to have been close to the stars o and ζ in the foot of *Perseus*, near the spot indicated by Mr. Newton and Mr. Bruce. Mr. Stein, however, probably from his seeing only a part of the sky, thinks there was no radiant point. I have not seen him, though, since I received his description; but from verbal explanations given by Mr. Bruce and Mr. Marsh, and from Captain Gaston's account, I think the meteors shot from the above-mentioned point. Mr. Bruce informs me that he observed a meteor pass from northward closs to and parallel with ε and α *Tauri*, and Mr. Marsh mentions that he saw one pass from near the zenith right over *Fomalhaut*.

I think there must be some mistake in the statement that many meteors shot from *Orion* through the zenith to the western horizon.

With regard to the time of maximum intensity, it must have been at 11, or soon after.

The shower was evidently not equal in splendour to that of the 24th Nov., 1866.

Watch was kept up during the night of the 28th to 29th, but the few meteors seen did not radiate from any point.

The number of meteors seen from the 12th to the 15th was not greater than on ordinary nights.

On referring to Quételet's Catalogue I find mention of only three showers seen about the 27th Nov.; one on the 25th Nov (16th Tul. Cal.), 1602, a second on the 25th Nov., 1822, and a third on the 29th Nov., 1850.

While on the subject of meteors, I beg to send an account of an extraordinary one seen here by the Rev. Mr. Wright on the evening of the 7th Nov. last. Mr. Wright's description in several respects applies to the Moon, which was at the end of her first quarter, and in the part of the heavens indicated. Has any similar meteor been seen in former times? It was totally different in form and appearance from the great meteor of Nov. 27, 1862.

Mauritius, 12th Dec., 1872.

Apparent Paths of 54 Shooting-Stars observed at Newcastle-on-Tyne, 1872, November 27th, 6h to 7h p.m.; with the Determination of their Radiant-Point. By Prof. A. S. Herschel, B.A., F.R.A.S.

No.	Approximate G.M.T.	Apparent Magnitude and Colour.	Duration.	Apparent Path. From α	From δ (+)	To α	To δ (+)	Direction,* as from *nearest point to Mean Radiant.* α	Direction,* as from *nearest point to Mean Radiant.* δ (+)	Least Deviation from Mean Radiant Point.	Length of Path; Streak, and its Duration.		Remarks.
	h m s		sec.	°	°	°	°	°	°	°	°	sec.	
1	6 2 0	1 br. wh.	1	338·5	29·5	1	14	..	..	..	20	none	Bright, swift. Unconformable.
2	2 30	3 wh.	0·6	349	22·5	347	18	5	47	12	5	„	Erratic (from *Cassiopeia*).
3	3 30	2 wh.	0·5	22·5	35	22·5	35	22·5	35	5	0	„	Almost stationary.
4	4 0	Sir. wh. or. r.	0·8	335	−1	327	−11	18	43	2	12	red; 3	Or. with r. sparks; strk. in mid course.
5	5 0	2	0·7	358	14	355	10	20	40	0	4		
6†	6 0	2 and 3	..	near		21	32	..	..	..	short		Three or four together, radiating from this place.
7	7 0	>1 wh. & r.	1·0	42	24	49	17	20	40	0	10	slight	Five others following it nearly on the same course.
8	9 0	2 wh.	0·8	351	21	344·5	15	20	40	0	9		
9	9 30	2	..	341·5	8	335	−0·5	18	41	2	10		Many bright ones, followed by a lull for one minute.
10	10 30	Sir. wh. r.	..	86	55	100	53	20	40	0	8	reddish, with spks	Brightest in mid-course.
11	11 30	2 wh.	..	44	40·5	55	36·5	21	44	4	10		
12	12 0	3 yel.	..	347	16	343·5	12·5	21	37·5	2·5	5		
13	13 0	2 and 3 yel.	..	64	51·5	73	51	23	34·5	6	6		Three meteors following each other on the same course.
14	13 30	Sir. wh. r.	0·9	265	83	232	72	32	40	8	12	or.; 3 s.	Golden yel. sparks in mid-course.
15	15 0	2 wh.	..	226	75	218	64	24	41	2·5	11	none	
16	18 0	2 wh.	..	342	65	324	69	16	38	4	8		Quite a burst of many meteors.
17	19 0	2 wh.	0·8	331	52·5	309	44	27	51	12	15		Many fine ones missed.
18	19 30	3 yel.	..	277	72	241	67	0	35	14	13	none	Erratic (from near α *Andromedæ*).
19	20 0	3	..	269	57	264	55	16	37·5	4	4		
20	20 15	2	..	277	54	269	51	15	36	5	5		Two radial groups with it, near and diverging from θ *Cassiopeiæ* and φ *Persei*.
21	21 0	3 yel.	..	343	47	333	45	23	47	6·5	6	none	
22	21 15	1	..	354	28	350	24	18	42	2·5	5		Two others near it, as from β *Andromedæ*.
23	21 30	2 and 3	..	305	54	292	51	18·5	39	1·5	7		Two close together, and parallel.
				[illegible]	[illegible]	340	65	20	40	8	12		

29	24 30	2 wh.	0·7	344	14·5	338	10	22	35	5	7		
30	25 0	3	..	1	49	351	46	15	51	11	5		
31	26 0	2 yel.	0·8	0	29	352	18	15	44	5	10		
32	26 15	2 or.	..	345	27	340·5	24	20	40	0	4		
33	26 30	Sir. yel.	..	324	49	306	41	24	49	9	15	2 secs.; or. yel.	Streak interrupted in the middle.
34	27 0	2	..	354	24	348	18	20	40	0	9		
35	27 0	>1 yel. or.	0·8	349	70	304	76·5	21	40	0·5	12	2 secs.	Five or six meteors missed for each of the last eight or ten recorded.
36	28 0	3	..	17	88·5	195	86	15	40	3·5	5		
37	28 30	1	..	331	56	308	49	27	51	11·5	15		
38	30 0	4 yel.	..	8	55	0	58	25	42·5	4·5	4		Followed instantly by one of 2nd mag. on the same course.
39	30 30	2	..	340	65	320	68	23	41	2	6		
40	30 45	2	..	262	52	255	46·5	23	42	3	8		
41	32 0	>2 yel.	..	23	35	..	..	23	35	5	0		Stationary at same point as No. 3.
42	34 0	2	..	11	30	4	19	20	40	0	12		
43	35 0	2	0·6	21	39	21·5	+39	20	39	1	0·5		Nearly stationary.
44	35 30	1 yel.	0·8	18	42·5	..	..	18	42·5	3	0	none	Quite stationary; a fine display of bright meteors just now.
45	37 0	2 yel.	..	280	57·5	269	51	29	45	8	10	1 sec.	
46	38 0	3	..	334	51	324	50·5	21	41	1	4		
47	38 15	>1	..	302	46	282	37	21	41	1	18	2 secs.	Followed by four others of 1 and 2 mags. in 15 secs.
48	38 45	1	..	322	45	314	43·5	19	38·5	1·5	5	1 sec.	
49	39 0	2	..	309	44	294	39	18·5	38·5	1·5	12		
50	40 0	3	..	313	41·5	304	39·5	16	34	6·5	7		
51	40 30	2	..	295	44	278·5	38·5	14	34·5	6	15		
52	43 0	2	..	300	53	292	51	18	39	1·5	5		
53	45 0	>1 wh. or.	0·8	319	54·5	302	48	28	49·5	10	12	streak	Much brighter in mid-course, and leaving a streak there.
54	55 0	1 yel.	0·7	338	10	330	3	22	35	5	9	none	Clouds covering half the sky.
55	57 0	2 yel.	0·7	326	0·5	321	−6	16·5	44	4·5	8	none	Afterwards quite overcast.
Average Duration (omitting No. 1)			0·75	Mean Radiant Point		..	20·0	40·6	4·2	8·0	Mean Deviation from Radiant, and Length of Path (omitting No. 1.)		

* Adopting, as *a provisional mean radiant*, a point in R.A. 20°, N. Decl. 40°. All the positions are taken from a star-chart for the epoch 1860.

† No. 6; a radial group almost simultaneous, diverging from a point between β *Andromedæ* and α *Trianguli*.

Star Shower observed at Malta on 27th November, 1872.

By Commander W. J. S. Wharton.

At sunset the evening was clear, and a great many aerolites were perceived. At 5.45, 250 were counted in ten minutes by two observers.

At 6, four observers, taking a quadrant of the heavens each, counted 298 in five minutes :—

N.E. quadrant	..	90
S.E. do.	..	75
S.W. do.	..	59
N.W. do.	..	74
Total		298

The shower steadily increased till at 7.45 P.M., the numbers counted were as follows :—

N.E.	..	245
S.E.	..	425
S.W.	..	293
N.W.	..	200
		1163 in 5 minutes.

At this time they were falling so fast that probably not two-thirds of the actual number visible were counted, it was impossible for one observer to take in a whole quadrant. The aerolites were, as a rule, small, and the paths short ; no bolides were observed. The radial point was as nearly as could be measured, in 37° N. declination and 0^h 40 R.A., not far from the star, *β Andromedæ*. This (the radial point) was, at 7.45, nearly in the zenith, and the stars fell on all sides. Immediately after this observation the clouds gathered, and the heavens were more or less obscured till 11 o'clock, but in the rifts the aerolites could be seen still falling rapidly. At 11 o'clock, when the sky was again clear, the numbers had greatly diminished, but there were still many visible. After this, the shower gradually dwindled away to nothing. Only two aerolites were observed that did not come from the radial point above mentioned, or its vicinity. No star track remained visible more than a few seconds.

H.M.S. Shearwater, at Malta,
2nd December, 1872.

Note on the Meteor Swarm of Nov. 27th, 1872.

By Charles E. Burton, B.A.

Communicated by G. Johnstone Stoney, Esq. (*Abstract.*)

The positions of the radiant point of the meteors which entered the Earth's atmosphere on the evening of the 27th of last Novem-

ber, were observed by Mr. Burton in the neighbourhood of Dublin at about the following hours of local time, $7^h\ 15^m$, $7^h\ 45^m$ and $8^h\ 15^m$.

The following table in which for more convenience the local times have been converted into Greenwich times presents Mr. Burton's results:—

Greenwich Mean Time. Nov. 27, 1872.	Position of Radiant Point. R.A.	N. P. D.
h m	° ′	° ′
7 40	17 0	43 30
8 10	19 30	45 10
8 40	22 25	46 25

Mr. Burton observed from a station nearly 25^m West longitude and 54° 12′ North latitude.

As regards the weight to be attached to the observations,—The first of Mr. Burton's observations was taken with a fair amount of care, and the other two with the utmost attainable accuracy, on account of his having been struck with the motion of the radiant point. His further observation was unfortunately stopped by cloud.

Ephemeris for Physical Observations of the Moon.

By A. Marth, Esq.

(*Communicated by R. S. Newall, Esq.*)

Though the phenomena attending sunrise and sunset on the Moon's surface have been frequently looked at, because affording some of the most striking and interesting of telescopic sights, they have in reality been so little "observed," or at least to so little practical purpose, that for want of the needed "observations" no exact prediction can yet be made of what phenomena may be expected to be seen at a given time or at what time some given phenomenon may be expected to recur. Yet the observations required for the purpose are of the simplest character, and can easily be made by zealous amateurs in possession of a good telescope and of Mädler's map of the Moon, who are willing to devote to them the needed time and patience. That such observations have not been abundantly made, is perhaps chiefly due to the want of a proper ephemeris of the Sun's selenographical position (such as has been published monthly for some time past in the *Astron. Register*), without which the observations cannot be made available for further use, but it may also be partly due to the simple circumstance, that some amateurs are perhaps not sufficiently aware, that by merely noting the time and the exact locality of the occurrence of some lunar phenomenon they secure the data needed for the prediction of its recurrence.

I submit new ephemerides supplying, for the next three lunations, the selenocentrical places of the Sun and also of the Earth,

referred to the system of selenographical co-ordinates. The ephemerides are given in the form which seems to me the most suitable for practical use. For the sake of obvious convenience, selenographical longitudes (λ) have been supplanted by their complements ($90° - \lambda$), and the latter are called "co-longitudes." Accordingly on the map the co-longitude of the preceding edge is 0°, that of the central meridian 90°, and that of the following edge 180°. The computations have been made so that the last figures given can be relied on. The assumed inclination of the equator to the lunar ecliptic is 1°·536.

I have also prepared a list comprising 600 lunar spots, which supplies the data for finding by means of a trifling computation, the Sun's co-longitude and consequently the time when the Sun's centre is in the true horizon of any of these spots. For the purpose it is only required to multiply the Sun's selenographical latitude by the factor given in the second (or, at sunset, the last) column of the list, to add the product to the number preceding the factor and to ascertain, by reference to the monthly ephemeris, the time when the Sun's centre reached the co-longitude thus found. For instance, we have for the evening of Feb. 5,—

At 6^h G.M.T.	Sun's colongitude 8°·72	Sun's latitude − 1°·50
12^h „	„ 11·76	„ „

Referring now to the list we find for *Plato* γ: — Sun's co-longitude at sunrise = 6°·8 − 1·20 × Sun's latitude = 6°·8 + 1°·80 = 8°·60, which the Sun's centre reaches about $5^h\ 46^m$. By making the same little computation for a series of spots and arranging the results in order of time, we get,—

		°	h
Sun's centre in true horizon of Plato γ (in lat.		50 N) at	5 46
„ „	Lalande	4 S	5 48
„ „	Eratosthenes E	15 N	6 59
„ „	Alpetragius C	14 S	7 58
„ „	Schröter C	8 N	7 58
„ „	Pico B	43 N	8 21
„ „	Lalande A	6 S	8 24
„ „	Archimedes B	27 N	9 3
„ „	Tycho	43 S	9 27
„ „	Pico	45 N	9 59
„ „	Guerike C	11 S	11 30
„ „	Pilatus C	28 S	11 42
„ „	Eratosthenes	14 N	12 8
„ „	Gambart B	2 N	12 22
„ „	Pico D	43 N	14 26
„ „	Plato E	51 N	15 56

The times thus found are merely the times when the Sun is

in the true horizon of the assumed selenographical positions of the spots. What is now wanted are real observations of the times and localities of the phenomena attending sunrise and sunset,—a class of observations which recommends itself strongly to amateurs, who can afford the time and are desirous to do useful service to science, provided it does not demand much computation. Will they give their help?

Sun's Co-longitudes

At Sunrise.			Latitude.	At Sunset.	
°			°	°	
279·0	+0·07	Kästner A	− 4·2	99·0	−0·07
282·74	− ·04	Schubert A	+ 2·46	102·74	+ ·04
284·5	−0·75	Gauss A	+36·8	104·5	+0·75
284·5	−1·38	Mare Humb. E	+54·1	104·5	+1·38
285·0	+0·70	Marinus E	−35·1	105·0	−0·70
286·00	− ·24	Hansen A	+13·29	106·00	+ ·24
286·12	+ ·17	Lapeyrouse A	− 9·39	106·12	− ·17
287·0	− ·52	Oriani A	+27·3	107·0	+ ·52
287·6	+ ·29	Behaim A	−16·1	107·6	− ·29
289·0	− ·09	Neper *a*	+ 5·0	109·0	+ ·09
290·0	+ ·51	Legendre *a*	−27·0	110·0	− ·51
290·4	+ ·12	Maclaurin D	− 6·6	110·4	− ·12
290·7	−0·37	Alhazen *a*	+20·1	110·7	+0·37
291·27	+1·00	Vega A	−44·95	111·27	−1·00
291·5	−0·22	Condorcet	+12·5	111·5	+0·22
291·9	−0·58	Hahn A	+30·05	111·9	+0·58
292·3	+1·87	Boussingault G	−61·9	112·3	−1·87
293·1	−0·69	Berosus B	+34·7	113·1	+0·69
293·9	+ ·07	Maclaurin E	− 3·7	113·9	− ·07
295·0	− ·26	Prom. Agarum	+14·8	115·0	+ ·26
295·1	− ·43	Eimmart	+23·5	115·1	+ ·43
295·22	− ·94	Struve B	+43·34	115·22	+ ·94
297·0	− ·14	Firmicus β	+ 8·1	117·0	+ ·14
297·3	+0·55	Hase *a*	−28·8	117·3	−0·55
297·3	−1·42	Endymion A	+54·8	117·3	+1·42
298·1	+1·12	Vega H	−48·2	118·1	−1·12
299·0	+0·35	Vendelinus B	−19·4	119·0	−0·35
299·4	− ·09	Apollonius E	+ 4·9	119·4	+ ·09
299·43	+ ·15	Langrenus B	−8·38	119·43	− ·15
300·1	+ ·25	Vendelinus A	−13·9	120·1	− ·25
300·3	+ ·01	Maclaurin C	− 0·4	120·3	− ·01
300·7	− ·59	Burckhardt B	+30·3	120·7	+ ·59
300·74	+ ·46	Petavius A	−24·65	120·74	− ·46
300·8	+ ·70	Furnerius B	−35·1	120·8	− ·70

Sun's Co-longitudes

At Sunrise.		Latitude.	At Sunset.	
°	′	°	°	′
301·2	— ·76	Messala B	+37·1	121·2	+ ·76
301·8	— ·67	Geminus C	+33·75	121·8	+ ·67
302·0	+ ·80	Fraunhofer G	−38·7	122·0	— ·80
302·14	+ ·65	Furnerius A	−33·10	122·14	— ·65
302·2	— ·19	Azout Δ	+10·75	122·2	+ ·19
302·5	+ ·07	Langrenus B	− 4·2	122·5	— ·07
303·8	+ ·38	Petavius B	−20·8	123·8	— ·38
303·9	— ·41	Cleomedes F.	+22·3	123·9	+ ·41
304·2	— ·83	Hook *d*	+39·8	124·2	+ ·83
304·5	+ ·46	Petavius Γ	−24·6	124·5	— ·46
305·3	+0·56	Snellius	−29·4	125·3	−0·56
305·69	−1·51	Endymion G	+56·48	125·69	+1·51
305·71	−0·54	Cleomedes A	+28·40	125·71	+0·54
306·13	— ·26	Picard	+14·46	126·13	+ ·26
306·9	+ ′62	Stevinus A	−32·0	126·9	— ·62
307·0	— ·22	Picard *α*	+12·5	127·0	+ ·22
307·0	−0·73	Messala *a*	+36·2	127·0	+0·73
307·3	+1·01	Steinheil F	−45·3	127·3	−1·01
307·7	−0·33	Picard A	+18·1	127·7	+0·33
308·0	+1·78	Hagecius K	−60·6	128·0	−1·78
308·0	−0·39	Picard *ξ*	+21·2	128·0	+0·39
309·0	+1·40	Biela A	−54·4	129·0	−1·40
309·4	+0·12	Goclenius A	− 7·0	129·4	−0·12
309·93	+ ·41	Biot	−22·34	129·93	— ·41
310·1	+ ·31	Cook B	−17·2	130·1	— ·31
310·3	−0·13	Taruntius A	+ 7·2	130·3	+0·13
310·79	−1·88	Thales	+61·97	130·79	+1·88
312·2	−0·41	Macrobius *f*	+22·1	132·2	+0·41
312·3	+ ·40	Biot A	−21·6	132·3	— ·40
312·5	+ ·54	Reichenbach *a*	−28·5	132·5	— ·54
312·6	−0·50	Tralles A	+26·8	132·6	+0·50
312·6	+1·05	Steinheil H	−46·4	132·6	−1·05
312·85	+0·03	Messier	− 1·98	132·85	−0·03
312·9	−1·00	Atlas A	+45·05	132·9	+1·00
313·1	−0·81	Franklin	+38·9	133·1	−0·81
313·3	+ ·32	Cook A	−17·55	133·3	— ·32
313·47	— ·29	Proclus	+16·15	133·47	+ ·29
313·6	+ ·74	Rheita A	−36·5	133·6	— ·74
314·03	— ·10	Taruntius	+ 5·67	134·03	+ ·10
314·34	−0·87	Cepheus A	+40·99	134·34	+0·87
314·6	+1·27	Rosenberger B	−51·7	134·6	−1·27
314·7	−1·52	Strabo D	+56·7	134·7	+1·52
314·8	+0·47	Borda Δ	−25·15	134·8	−0·47

At Sunrise.		Sun's Co-longitudes Latitude.		At Sunset.	
°			°	°	
315·1	+ ·10	Messier A	− 5·8	135·1	− ·10
315·2	− ·21	Palus Somnii B	+11·8	135·2	+ ·21
315·5	− ·52	Römer G	+27·5	135·5	+ ·52
315·55	+ ·18	Goclenius A	− 9·98	135·55	− ·18
315·7	−0·38	Macrobius	+20·6	135·7	+0·38
316·3	−1·04	Atlas Γ	+46·1	136·3	+1·04
316·4	+0·83	Metius B	−39·7	136·4	−0·83
316·5	−1·24	Hercules A	+51·2	136·5	+1·24
317·5	−0·05	Taruntius B	+ 2·6	137·5	+0·05
317·5	+ ·37	Santbech B	−20·5	137·5	− ·37
318·1	− ·24	Palus Somnii A	+13·5	138·1	+ ·24
318·4	+ ·45	Santbech A	−24·2	138·4	− ·45
318·5	+0·07	Messier C	− 4·0	138·5	−0·07
318·7	+1·04	Fabricius K	−46·0	138·7	−1·04
318·9	+0·23	Colombo A	−12·9	138·9	−0·23
319·0	−2·54	Arnold *a*	+68·5	139·0	+2·54
319·23	+0·90	Fabricius A	−42·13	139·23	−0·90
319·9	−0·07	Taruntius F	+ 4·1	139·9	+0·07
320·0	+1·62	Nearch. A	−58·3	140·0	−1·62
320·1	−0·36	Macrobius *a*	+19·6	140·1	+0·36
320·2	+ ·16	Guttemberg A	− 9·2	140·2	− ·16
320·4	+ ·28	Bohnenberger A	−15·45	140·4	− ·28
320·5	− ·57	Römer *c*	+29·5	140·5	+ ·57
320·6	+ ·60	Neander A	−31·0	140·6	− ·60
320·9	−0·76	Cepheus B	+37·0	140·9	+0·76
321·61	−1·05	Hercules	+46·39	141·61	+1·05
321·8	−0·18	Sansen A	+10·1	141·8	+0·18
323·1	+ ·13	Capella A	− 7·6	143·1	− ·13
323·3	+1·28	Vlacq A	−52·0	143·3	−1·28
323·5	+0·52	Neander A	−27·3	143·5	−0·52
323·5	+ ·38	Fracastor. H	−20·9	143·5	− ·38
323·6	+ ·75	Stiborius A	−37·0	143·6	− ·75
323·68	− ·47	Römer	+25·31	143·68	+ ·47
324·3	−0·63	Posidonius G	+32·2	144·3	+0·63
324·4	+1·03	Fabricius C	−45·9	144·4	−1·03
324·8	−0·37	Maraldi	+20·4	144·8	+0·37
324·8	−1·72	Gärtner A	+59·8	144·8	+1·72
325·20	+0·13	Capella A	− 7·54	145·20	−0·13
325·5	−1·21	Baily B	+50·45	145·5	+1·21
326·2	+3·31	Euctemon B	+73·2	146·2	+3·31
326·3	+0·31	Fracastor. E	−17·45	146·3	−0·31
326·5	−0·71	Posidonius K	+35·5	146·5	+0·71
326·49	−1·89	Democritus	+62·14	146·49	+1·89

Sun's Co-longitudes At Sunrise.		Latitude.	At Sunset.	
326°·6	−0·32	Vitruvius A	+17°·6	146°·6	+0·32
326·9	+ ·14	Isidorus A	− 8·0	146·9	− ·14
327·64	+ ·01	Censorinus	− 0·44	147·64	− ·01
327·7	− ·15	Sansen C	+ 8·8	147·7	+ ·15
327·7	− ·85	Posidonius D	+40·2	147·7	+ ·85
327·7	+ ·94	Fabricius G	−43·2	147·7	− ·94
328·1	+ ·68	Stiborius A	−34·3	148·1	− ·68
328·41	+0·56	Piccolomini Δ	−29·18	148·41	−0·56
328·5	+1·62	Hommel *f*	−58·3	148·5	−1·62
328·6	+0·41	Fracastor. *α*	−22·4	148·6	−0·41
328·97	− ·32	Vitruvius	+17·60	148·97	+ ·32
329·4	−0·71	Posidonius C	+35·55	149·4	+0·71
329·6	−1·13	Baily A	+48·6	149·6	+1·13
329·9	−0·64	Littrow *α*	+32·8	149·9	+0·64
329·9	− ·91	Mason	+42·3	149·9	+ ·91
330·4	+ ·19	Theophilus A	−11·0	150·4	− ·19
330·42	−0·04	Maskelyne	+ 2·53	150·42	+0·04
330·45	+1·19	Pitiscus A	−49·98	150·45	−1·19
330·5	+0·47	Piccolomini A	−25·4	150·5	−0·47
330·64	+1·97	Mutus	−63·10	150·64	−1·97
330·7	+0·08	Torricelli A	− 4·3	150·7	−0·08
330·8	+ ·35	Beaumont C	−19·4	150·8	− ·35
330·88	− ·62	Posidonius A	+31·59	150·88	+ ·62
330·9	+ ·80	Riccius *d*	−39·6	150·9	− ·80
330·94	− ·49	Le Monnier A	+25·99	150·94	+ ·49
331·0	− ·21	Sansen, pic.	+11·75	151·0	+ ·21
331·8	−0·35	Vitruvius *α*	+19·4	151·8	+0·35
331·47	−1·00	Bürg	+44·95	152·47	+1·00
332·5	+0·28	Beaumont A	−15·8	152·5	−0·28
332·5	+ ·71	Riccius A	−35·2	152·5	− ·71
333·3	+ ·41	Polybius A	−22·1	153·3	− ·41
333·70	+ ·20	Theophilus A	−11·35	153·70	− ·20
334·0	− ·31	Plinius A	+17·0	154·0	+ ·31
334·3	+ ·04	Torricelli C	− 2·1	154·3	− ·04
334·6	+ ·90	Nicolai	−42·0	154·6	− ·90
334·9	+ ·48	Polybius B	−25·5	154·9	− ·48
335·4	− ·58	Posidonius *γ*	+30·0	155·4	+ ·58
335·51	+0·62	Lindenau	−31·87	155·51	−0·62
335·7	+2·54	Manzinus *α*	−68·5	155·7	−2·54
335·9	+0·12	Theophilus E	− 6·7	155·9	−0·12
335·9	+0·32	Catharina *α*	−17·6	155·9	−0·32
336·44	−1·57	Aristoteles C	+57·43	156·44	+1·57
336·61	−0·27	Plinius	+15·29	156·61	+0·27

Sun's Co-longitudes

At Sunrise.		Latitude.	At Sunset.	
336°7	− ·98	Bürg B	+44°5	156°7 + ·98
337°0	+ ·79	Büsching B	−38·4	157·0 − ·79
337·31	+ ·24	Cyrillus A	−13·50	157·31 − ·24
337·7	− ·70	Posidonius E	+34·9	157·7 + ·70
337·7	+ ·09	Hypatia A	− 4·9	157·7 − ·09
337·8	+ ·52	Pons *c*	−27·6	157·8 − ·52
338·4	− ·30	Prom. Acherusia	+16·45	158·4 + ·30
338·4	+ ·18	Kant A	−10·4	158·4 − ·18
338·5	− ·21	Ross	+11·6	158·5 + ·21
338·5	+ ·35	Catharina A	−19·3	158·6 − ·35
338·8	−0·11	Arago	+ 6·1	158·8 +0·11
338·9	+1·35	Baco *a*	−53·4	158·9 −1·35
339·0	+0·02	Hypatia C	− 1·0	159·0 −0·02
339·4	− ·47	Bessel A	+25·0	159·4 + ·47
339·5	− ·25	Menelaus A	+14·3	159·5 + ·25
340·0	− ·08	Arago A	+ 4·6	160·0 + ·08
340·3	+0·75	Büsching C	−37·0	160·3 −0·75
340·4	−1·02	Eudoxus A	+45·5	160·4 +1·02
340·4	−1·19	Aristoteles *a*	+49·9	160·4 +1·19
340·5	+0·41	Fermat A	−22·1	160·5 −0·41
340·6	− ·59	Posidonius E	+30·4	160·6 + ·59
341·0	+ ·10	Alfraganus	− 5·5	161·0 − ·10
341·1	− ·30	Taquet	+16·5	161·1 + ·30
341·4	− ·02	Ritter A	+ 0·9	161·4 + ·02
341·6	+ ·60	Zagut *d*	−31·1	161·6 + ·60
342·0	+ ·28	Tacitus A	−15·9	162·0 + ·28
342·0	− ·86	Eudoxus Δ	+40·6	162·0 + ·86
342·0	+0·86	Buch A	−40·7	162·0 −0·86
342·0	+1·05	Barocius β	−46·3	162·0 −1·05
342·4	−0·40	Bessel	+21·7	162·4 +0·40
342·6	− ·16	Sosigenes	+ 8·9	162·6 + ·16
342·75	+ ·03	Delambre	−1·79	162·75 − ·03
342·8	− ·96	Eudoxus α	+43·9	162·8 + ·96
342·87	− ·05	Dionysius	+ 2·85	162·87 + ·05
343·4	+ ·38	Sacrobosco F	−21·0	163·4 − ·38
343·7	+0·09	Taylor Γ	− 5·25	163·7 −0·09
343·9	+1·66	Ch. Mayer A	+59·0	163·9 +1·66
344·2	−0·29	Menelaus	+16·2	164·2 +0·29
344·32	+0·44	Sacrobosco A	−23·7	164·32 −0·44
344·4	−2·81	Meton B	+70·4	164·4 +2·81
344·5	−0·74	Calippus K	+36·6	164·5 +0.74
344·6	+0·01	Theon sen.	− 0·7	164·6 −0·01
344·8	+1·59	Jacobi *a*	−57·9	164·8 −1·59

Sun's Co-longitudes

At Sunrise.		Latitude.		At Sunset.	
345°0	−0·07	Dionysius A	+ 4°0	165°0	+0·07
345·0	+0·32	Almanon A	−17·5	165·0	−0·32
345·3	−1·20	Aristoteles α	+50·1	165·3	+1·20
345·6	+0·53	Pontanus	−27·7	165·6	−0·53
345·80	+0·18	Dollond	−10·25	165·80	−0·18
345·9	+1·08	Clairaut D	−47·3	165·9	−1·08
346·0	−0·17	Cæsar β	+ 9·4	166·0	+0·17
346·0	−0·59	Linné B	+30·6	166·0	+0·59
346·0	+3·87	Simpelius	−75·5	166·0	−3·87
346·3	+0·36	Geber A	−19·6	166·3	−0·36
346·32	+ ·95	Maurolycus A	−43·39	166·32	− ·95
346·4	+ ·70	Gemma Fris. B	−35·0	166·4	− ·70
346·4	+ ·24	Abulfeda A	−13·6	166·4	− ·24
346·9	− ·31	Sulpicius A	+17·3	166·9	+ ·31
347·4	− ·93	Eudoxus D	+42·9	167·4	+ ·93
347·5	−0·11	Silberschlag	+ 6·5	167·5	+0·11
347·5	−4·01	Scoresby	+76·0	167·5	+4·01
347·8	+0·06	Taylor A	− 3·5	167·8	−0·06
348·46	− ·53	Limé	+27·79	168·46	+ ·53
348·6	+ ·84	Maurolycus B	−40·1	168·6	− ·84
348·7	−0·35	Sulpicius Gallus	+19·5	168·7	+0·35
349·2	+2·02	Pentland A	−63·7	169·2	−2·02
349·2	+0·45	Azophi A	−24·3	169·2	−0·45
349·4	− ·16	Boscovich A	+ 9·1	169·4	+ ·16
349·4	+ ·60	Poisson δ	−30·9	169·4	− ·60
349·5	+ ·29	Abulfeda A	−16·2	169·5	− ·29
349·5	− ·94	Cassini α	+43·1	169·5	+ ·94
349·63	− ·07	Agrippa	+ 4·07	169·63	+ ·07
349·8	− ·79	Calippus	+38·4	169·8	+ ·79
349·9	− ·03	Godin	+ 1·7	169·9	+ ·03
350·0	−0·21	Manilius C	+12·0	170·0	+0·21
350·3	−1·27	Egede A	+51·7	170·3	+1·27
350·5	−1·12	Egede	+48·3	170·5	+1·12
350·6	+0·02	Hipparch. M	− 1·4	170·6	−0·02
350·9	+ ·96	Stöfler D	−43·7	170·9	− ·96
351·22	− ·26	Manilius	+14·45	171·22	+ ·26
351·6	+0·51	Apianus B	−27·0	171·6	−0·51
351·7	−2·01	Archytas C	+63·5	171·7	+2·01
351·7	+0·13	Hipparch. C	− 7·3	171·7	−0·13
351·9	+ ·80	Stöfler L	−38·8	171·9	− ·80
352 0	+ ·31	Airy A	−17·3	172·0	− ·31
352·0	−0·49	Hadley Γ	+26·1	172·0	+0·49
352·4	+1·18	Cuvier α	−49·7	172·4	−1·18

Sun's Co-longitudes at Sunrise.		Latitude.		Sun's Co-longitudes at Sunset.	
°			°	°	
352·8	−0·89	Cassini C	1	172·8	+0·89
352·9	− ·30	Manilius B	+16·6	172·9	+ ·30
353·0	+0·05	Hipparch. E	− 2·8	173·0	−0·05
353·0	+1·75	Zach B	−60·3	173·0	−1·75
353·2	−0·62	pic	+31·7	173·2	+0·62
353·3	− ·03	Rhäticus B	+ 1·7	173·5	+ ·03
353·3	−0·23	Manilius D	+13·1	173·3	+0·23
353·4	−1·44	Archytas A	+55·3	173·4	+1·44
353·6	+0·65	Nonius B	−33·1	173·6	−0·65
353·6	− ·14	Hyginus	+ 8·0	173·6	+ ·14
353·8	+ ·23	Albategnius E	−13·0	173·8	− ·23
354·1	+ ·47	Apianus A	−25·4	174·1	− ·47
354·3	+ ·14	Hipparch. A	− 8·1	174·3	− ·14
354·4	− ·74	Theætetus	+36·4	174·4	+ ·74
354·5	−0·52	Hadley β	+27·4	174·5	+0·52
354·6	−1·16	Egede *d*	+49·3	174·6	+1·16
354·7	−0·03	Rhäticus A	+ 1·7	174·7	+0·03
354·7	+1·39	Lilius A	−54·3	174·7	−1·39
354·9	+0·96	Stöfler E	−43·7	174·9	−0·96
355·0	+ ·29	Airy C	−16·0	175·0	− ·29
355·3	− ·99	Cassini G	+44·7	175·3	+ ·99
355·4	+ ·58	Aliacensis A	−30·3	175·4	− ·58
355·5	−0·43	Aratus	+23·5	175·5	+0·43
355·78	−1·63	Archytas	+58·40	175·78	+1·63
355·85	−0·85	Cassini A	+40·38	175·85	+0·85
356·03	+ ·20	Albateguius A	−11·36	176·03	− ·20
356·1	− ·07	Triesnecker	+ 4·2	176·1	+ ·07
356·12	+ ·37	La Caille A	−20·5	176·2	− ·37
356·6	+ ·81	Stöfler K	−39·15	176·6	− ·81
356·8	− ·37	Conon A	+20·4	176·8	+ ·37
357·03	+ ·53	Werner A	−27·76	177·03	− ·53
357·1	+1·96	Curtius B	−63·0	177·1	−1·96
357·2	−0·55	Autolycus γ	+28·6	177·2	+0·55
358·0	+ ·14	Hipparch. K	− 7·9	178·0	− ·14
358·05	− ·39	Conon	+21·53	178·05	+ ·39
358·1	+0·24	Parrot B	−13·4	178·1	−0·24
358·2	−3·11	Barrow A	+72·2	178·2	+3·11
358·3	−0·44	Bradley A	+23·55	178·3	+0·44
358·6	− ·13	Ukert	+7·55	178·6	+ ·13
358·6	+ ·05	Réaumur A	− 2·7	178·6	− ·05
358·8	+ ·94	Licetus G	−43·35	178·8	− ·94
358·9	− ·07	Triesnecker A	+ 3·95	178·9	+ ·07
358·9	+ ·36	La Caille C	−19·95	178·9	− ·36

Sun's Co-longitudes

At Sunrise.		Latitude.		At Sunset.	
358°·99	− ·67	Aristillus	+33°·76	178°·99	+ ·67
359·0	− ·91	Cassini *n*	+42·2	179·0	+ ·91
359·4	+ ·51	Werner A	−27·1	179·4	− ·51
359·6	− ·01	Triesnecker B	+ 0·7	179·6	+ ·01
359·6	− ·56	Autolycus A	+29·1	179·6	+ ·56
359·6	+ ·61	Walter A	−31·4	179·6	− ·61
359·9	+0·08	Réaumur A	− 4·4	179·9	−0·08
0·0	+2·16	Curtius δ	−65·2	180·0	−2·16
0·0	+0·79	Nasireddin *a*	−38·3	180·0	−0·79
0·6	+1·07	Saussure *d*	−47·0	180·6	−1·07
0·7	+0·16	Ptolemäus A	− 8·9	180·7	−0·16
0·8	−1·23	Plato A	+50·9	180·8	+1·23
1·0	−1·92	Timäus	+62·45	181·0	+1·92
1·3	−0·16	Bode A	+ 8·9	181·3	+0·16
1·3	− ·85	Pico A	+40·3	181·3	+ ·85
1·3	+ ·53	Regiomont. A	−27·8	181·3	− ·53
1·8	− ·61	Archimedes C	+31·4	181·8	+ ·61
2·15	+ ·10	Herschel	− 5·62	182·15	− ·10
2·2	− ·25	Marco Polo A	+14·2	182·2	+ ·25
2·2	+ ·33	Arzachel A	−18·1	182·2	− ·33
2·51	−0·12	Bode	+ 6·62	182·51	+0·12
2·5	+1·38	Deluc H	−54·1	182·5	−1·38
2·55	−0·37	Huyghens	+20·4	182·5	+0·37
2·6	+ ·75	Lexell *a*	−36·7	182·6	− ·75
2·6	+0·49	Purbach A	−25·9	182·6	−0·46
3·0	+2·00	Cysatus A	−63·4	183·0	−2·00
3·24	+0·23	Alphons A	−12·99	183·24	−0·23
3·6	+0·91	Saussure B	−42·4	183·6	− ·91
3·7	−0·89	Pico A	+41·75	183·7	+0·89
4·1	−1·15	Plato *μ*	+49·1	184·1	+1·15
4·2	+0·54	Regiomont. B	−28·5	184·2	−0·54
4·4	− ·21	Bode C	+12·0	184·4	+ ·21
4·6	+ ·17	Ptolemæus *α*	− 9·4	184·6	− ·17
4·8	+ ·77	Lexell B	−37·6	184·8	− ·77
4·9	−0·43	Archimedes A	+23·1	184·9	+0·43
5·0	−2·56	Epigenes B	+68·7	185·0	+2·56
5·22	+0·06	Mösting A	−3·18	185·22	−0·06
5·2	+1·14	Maginus A	−48·85	185·2	−1·14
5·4	+0·46	Purbach K	−24·9	185·4	−0·46
5·4	−0·71	Kirch β	+35·2	185·4	+0·71
5·5	+1·75	Deluc E	−60·3	185·5	−1·75
5·79	+0·39	Thebit A	−21·29	185·79	−0·39
5·9	+ ·01	Mösting	− 0·6	185·9	− ·01

At Sunrise.		Sun's co-longitudes Latitude.		At Sunset.	
6°·1	− ·81	Kirch	+39°·1	186°·1	+ ·81
6·5	− ·53	Archimedes A	+27·9	186·5	+ ·53
6·6	−0·05	Schröter A	+ 3·0	186·6	+0·05
6·8	−1·20	Plato γ	+50·2	186·8	+1·20
6·9	+0·82	Sasserides *d*	−39·4	186·9	−0·82
7·10	+1·19	Maginus A	−49·95	187·10	−1·19
7·14	+2·71	Moretus	−69·76	187·14	−2·71
7·4	−0·12	Schröter Γ	+ 6·6	187·4	+0·12
7·4	+ ·27	Alpetragius B	−14·9	187·4	− ·27
7·7	− ·30	Wolf	+16 6	187·7	+ ·30
8·1	+ ·21	Davy A	−12·1	188·1	− ·21
8·1	+0·44	Thebit A	−23·7	188·1	−0·44
8·3	+1·00	Pictet *a*	−44·9	188·3	−1·00
8·33	+0·62	Hell	−31·98	188·33	−0·62
8·4	+1·49	Clavius K	−56·2	188·4	−1·49
8·5	−0·94	Pico B	+43·1	188·5	+0·94
8·74	+ ·08	Lalande	− 4·33	188·74	− ·08
8·75	+ ·35	Thebit D	−19·5	188·75	− ·35
8·8	− ·28	Eratosthenes E	+15·4	188·8	+ ·28
9·1	+0·71	Sasserides B	−35·5	189·1	−0·71
9·21	−1·92	Pico	+45·47	189·21	+1·02
9·5	−0·51	Archimedes B	+27·2	189·5	+0·51
9·5	− ·14	Schröter C	+ 8·1	189·5	+ ·14
9·6	+ ·93	Tycho, prec. wall	−42·9	189·6	− ·93
10·1	+ ·11	Lalandé A	− 6·4	190·1	− ·11
10·1	+0·26	Alpetragius C	−14·4	190·1	−0·26
10·4	−1·86	Fontenelle *b*	+61·7	190·4	+1·86
10·52	−2·46	Epigenes H	+67·89	190·52	+2·46
10·9	+1·34	Maginus H	−53·2	190·9	−1·34
11·44	−0·26	Eratosthenes C	+14·44	191·44	+0·26
11·6	− ·93	Pico D	+42·9	191·6	+ ·93
11·6	+ ·20	Guerike C	−11·2	191·6	− ·20
11·87	+ ·93	Tycho	−42·87	191·87	− ·93
11·9	−0·03	Gambart B	+ 1·95	191·9	+0·03
11·9	−1·23	Plato E	+50·8	191·9	+1·23
12·3	+5·00	Newton	−78·7	192·3	−5·00
12·4	+0·53	Pilatus C.	−28·1	192·4	−0·53
12·5	+2·27	Grümberger A	−66·25	192·5	−2·27
12·5	+1·75	Clavius *a*	−60·2	192·7	−1·75
13·00	−0·50	Timocharis	+26·71	193·00	+0·50
13·1	+ ·40	Thebit C	−21·65	193·1	− ·40
13·4	+ ·03	Lalande E	− 1·6	193·4	+ ·20
13·4	− ·20	Stadius B	+11·4	193·4	− ·03

Sun's co-longitudes

At Sunrise.			Latitude.	At Sunset.	
13°·5	+ ·69	Gauricus *a*	−34°·7	193°·5	− ·69
13·8	+ ·18	Guerike A	−10·3	193·8	− ·18
14·0	−0·08	Gambart *ε*	+ 4·8	194·0	+0·08
14·4	+1·00	Tycho *d*	−45·0	194·4	−1·00
14·67	+1·56	Clavius C	−57·28	194·67	−1·56
15·2	+0·25	Guerike B	−14·1	195·2	−0·25
15·3	−0·02	Gambart	+ 1·0	195·3	+0·02
15·5	−1·04	Pico B	+46·1	195·5	+1·04
15·6	+0·04	Fra Mauro H	− 2·4	195·6	−0·04
15·6	−2·19	Fontenelle A	+65·5	195·6	+2·19
15·66	+0·16	Parry A	− 9·33	195·66	−0·16
15·7	− ·66	Carlini D	+33·4	195·7	+ ·66
16·3	+ ·08	Fra Mauro A	− 4·5	196·3	− ·08
16·99	+ ·51	Hesiodus B	−26·84	196·99	− ·51
17·	+ ·81	Heinsius *a*	−39·	197·	− ·81
17·0	+0·19	Guerike A	−10·95	197·0	−0·19
17·4	−3·02	Anaxagoras Δ	+71·7	197·4	+3·02
17·9	−1·31	Plato B	+52·6	197·9	+1·31
18·0	−0·49	Lambert Γ	+25·9	198·0	+0·49
18·0	−0·27	Gay Lussac *ι*	+15·1	198·0	+0·27
18·0	+1·16	Longomont. *α*	−49·3	198·0	+1·16
18·4	+0·35	Bulliald D	−19·25	198·4	−0·35
18·5	− ·16	Copernicus A	+ 9·1	198·5	+ ·16
18·7	+ ·64	Cichus B	−32·7	198·7	− ·64
18·75	− ·01	Gambart A	+0·84	198·75	+ ·01
19·7	+0·24	Lubiniezki A	−13·7	199·7	−0·24
19·7	−1·95	Fontenelle B	+62·8	199·7	+1·95
19·9	−1·01	Laplace F	+45·2	199·9	+1·01
19·93	−0·16	Copernicus B	+9·35	199·93	+0·16
20·00	−0·10	Copernicus A	+ 5·8	200·0	+0·10
20·2	+1·99	Blancanus A	−63·3	200·2	−1·99
20·4	−0·23	Gay Lussac A	+13·1	200·4	+0·23
20·4	− ·84	Helicon A	+40·2	200·4	+ ·84
20·57	− ·37	Pytheas	+20·23	200·57	+ ·37
20·7	− ·58	Carlini B	+30·0	200·7	+ ·58
20·7	+ ·10	Fra Mauro A	− 5·5	200·7	− ·10
20·85	− ·47	Lambert	+25·35	200·85	+ ·47
21·4	− ·08	Reinhold A	+ 4·3	201·4	+ ·08
21·6	+ ·43	Bulliald. B	−23·4	201·6	− ·43
22·0	+ ·99	Wilhelm A	−44·5	202·0	− ·99
22·10	+ ·37	Bullialdus	−20·43	202·10	− ·37
22·6	− ·05	Reinhold	+ 3·1	202·6	+ ·05
22·7	+ ·55	Kies A	−28·6	202·7	− ·55

At Sunrise.		Sun's co-longitudes Latitude.		At Sunset.	
°			°	°	
22·9	− ·84	Helicon	+40·2	202·9	+ ·84
23·0	− ·13	Copernicus B	+ 7·4	203·0	+ ·13
23·1	+ ·70	Capuanus δ	−34·9	203·1	− ·70
23·3	+0·26	Lubiniezki B	−14·4	203·3	−0·26
23·4	−1·07	Laplace B	+46·9	203·4	+1·07
23·5	+1·33	Longomont. A	−53·0	203·5	−1·33
24·0	−1·36	Condamine E	+53·7	204·0	+1·36
24·01	−0·66	Carlini	+33·38	204·01	+0·66
24·2	+ ·44	Bulliald C	−23·9	204·2	− ·44
24·4	− ·28	Gay Lussac ν	+15·7	204·4	+ ·28
24·6	+ ·55	Mercator *b*	−28·7	204·6	− ·55
25·16	−0·52	Lahire	+27·31	205·16	+0·52
25·3	−1·01	Laplace A	+45·4	205·3	+1·01
25·6	+0·25	Lubiniezki C	−13·8	205·6	−0·25
25·6	−1·86	Fontenelle C	+61·8	205·6	+1·86
26·0	−0·22	Meyer C	+12·4	206·0	+0·22
26·4	+ ·36	Agatharchides δ	−19·7	206·4	− ·36
26·56	− ·94	Laplace A	+43·27	206·56	+ ·94
26·56	+0·01	Landsberg	−0·50	206·56	−0·01
26·60	+1·73	Scheiner A	−59·97	206·60	−1·73
26·8	−0·17	Milichius B	+ 9·4	206·8	+0·17
27·0	+0·67	Capuanus B	−33·9	207·0	−0·67
27·0	+3·19	Klaproth *b*	−72·6	207·0	−3·19
27·2	+0·15	Euclides B	− 8·6	207·2	−0·15
27·2	−1·14	Maupertuis Z	+48·8	207·2	+1·14
27·45	+0·52	Campanus	−27·61	207·45	−0·52
27·45	+1·13	Bayer B	−48·5	207·45	−1·13
27·6	+0·84	Hainzel C	−40·1	207·6	−0·84
27·9	− ·12	Hortensius	+ 6·9	207·9	+ ·12
28·2	+ ·05	Landsberg B	− 2·6	208·2	− ·05
28·83	− ·28	Mayer	+15·54	208·83	+ ·28
28·95	−0·42	Euler	+22·96	208·95	+0·42
29·2	+1·24	Bayer A	−51·1	209·2	−1·24
29·26	+0·33	Euclides	−7·17	209·26	−0·13
29·41	+0·93	Hainzel A	−42·99	209·41	−0·93
29·5	−1·38	Condamine *a*	+54·0	209·5	+1·38
29·7	+0·33	Agatharchides H	−18·1	209·7	−0·33
29·8	−1·59	Condamine B	+57·9	209·8	+1·59
29·9	−0·18	Milichius	+10·3	209·9	+0·18
30·1	+0·19	Euclides B	−11·0	210·1	−0·19
30·7	+1·66	Scheiner B	−59·0	210·7	−1·66
30·7	·00	Landsberg A	− 0·1	210·7	·00
30·8	+0·58	Ramsden A	−30·2	210·8	−0·58

Sun's co-longitudes

At Sunrise.		Latitude.		At Sunset.	
°			°	°	
30·9	− ·26	Mayer Δ	+14·3	210·9	+ ·26
31·0	+ ·77	Hainzel B	−37·6	211·0	− ·77
31·5	− ·68	Delisle C	+34·3	211·5	+ ·68
31·70	+ ·64	Ramsden α	−32·43	211·70	− ·64
31·9	− ·31	Mayer β	+17·0	211·9	+ ·31
32·3	− ·63	Delisle *b*	+32·3	212·3	+ ·63
32·3	− ·05	Encke A	+ 3·0	212·3	+ ·05
32·5	+0·72	Hippalus B	−35·8	212·5	−0·72
32·7	−1·11	Bianchini γ	+47·9	212·7	+1·11
33·8	+0·23	Gassendi D	−13·1	213·8	−0·23
33·8	− ·52	Diophantus	+27·4	213·8	+ ·52
34·02	− ·87	Heraclides	+41·13	214·02	+ ·87
34·3	−0·37	Euler B	+20·4	214·3	+0·37
34·7	+1·26	Bayer	−51·6	214·7	−1·26
34·80	−0·58	Delisle	+29·99	214·80	+0·58
35·3	−0·13	Kepler B	+ 7·4	215·3	+0·13
35·6	−1·30	Bouguer	+52·5	215·6	+1·30
35·7	+0·67	Ramsden D	−33·65	215·7	−0·67
35·8	+1·61	Weigel A	−58·1	215·8	−1·61
36·0	+0·94	Hainzel F	−43·1	216·0	−0·94
36·0	+ ·47	Döppelmayer D	−25·35	216·0	− ·47
36·4	−0·06	Encke ε	+ 3·5	216·4	+0·06
36·5	+1·06	Schiller A	−46·7	216·5	−1·06
36·6	−0·38	Euler A	+20·8	216·6	+0·38
36·9	+0·39	Gassendi S	−21·3	216·9	−0·39
37·0	+2·69	Wilson α	−69·6	217·0	−2·69
37·1	−0·26	Bessarion	+14·6	217·1	+0·26
37·12	+ ·58	Vitello	−30·01	217·12	−0·58
37·5	+ ·14	Euclides *a*	− 7·8	217·5	− ·14
37·71	−0·14	Kepler	+7·77	217·71	+0·14
38·0	−1·04	Sharp B	+46·2	218·0	+1·04
38·5	+0·10	Flamsteed Γ	− 5·5	218·5	−0·10
39·0	+ ·21	Letronne A	−11·9	219·0	− ·21
39·0	− ·38	Euler C	+21·0	219·0	+ ·38
39·2	+ ·76	Drebbel α	−37·3	219·2	− ·76
39·4	− ·71	Mairan *b*	+35·4	219·4	+ ·71
39·5	− ·80	Mairan A	+38·5	219·5	+ ·80
39·53	+0·30	Gassendi	−16·93	219·53	−0·30
39·6	−1·60	Horrebow	+58·0	219·6	+1·60
39·7	−0·30	Bessarion A	+16·6	219·7	+0·30
29·7	−0·64	Delisle A	+32·8	219·7	+0·64
40·0	+1·31	Schiller α	−52·7	220·0	−1·31
40·1	−1·20	Harpalus A	+50·1	220·1	+1·20

At Sunrise.		Sun's co-longitudes Latitude.		At Sunset.	
°			°	°	
40·2	·00	Encke E	0·0	220·2	·00
40·3	+2·01	Bettinus	−63·6	220·3	−2·01
40·5	−0·53	Aristarch. Δ	+27·9	220·5	+0·53
40·7	−1·01	Sharp	+45·2	220·7	+1·01
41·1	+0·08	Flamsteed *f*	− 4·85	221·1	−0·08
41·1	+ ·53	Döppelmayer A	−28·0	221·1	− ·53
41·3	+ ·20	Letronne B	−11·2	221·3	− ·20
41·3	− ·58	Wollaston A	+30·05	221·3	+ ·58
41·4	− ·35	Bessarion D	+19·3	221·4	+ ·35
41·5	− ·17	Kepler C	+ 9·8	221·5	+ ·17
42·3	− ·28	Bessarion C	+15·6	222·3	+ ·28
43·0	+ ·14	Flamsteed A	− 7·85	223·0	− ·14
43·3	+0·33	Gassendi A	−18·1	223·3	−0·33
43·61	−1·30	Harpalus	+52·48	223·61	+1·30
44·1	−1·09	Sharp A	+47·6	224·1	+1·09
44·20	+0·08	Flamsteed	− 4·51	224·20	−0·08
44·5	+1·12	Phocylides *d*	−48·2	224·5	−1·12
44·6	+0·27	Gassendi F	−15·15	224·6	−0·27
44·7	− ·89	Mairan	+41·7	224·7	+ ·89
44·9	−0·02	Reiner F.	+ 0·9	224·9	+0·02
45·0	+1·62	Segner	−58·3	225·0	−1·62
45·4	+0·52	Döppelmeyer β	−27·5	225·4	−0·52
45·5	−1·65	Horrebow A	+58·8	225·5	+1·65
45·6	−0·21	Marius A	+12·1	225·6	+0·21
45·6	+ ·45	Mersenius F	−24·14	225·6	− ·45
45·7	+ ·35	Mersenius C	−19·3	225·7	− ·35
45·9	+ ·10	Flamsteed C	− 5·7	225·9	− ·10
46·90	−0·58	Wollaston	+30·29	226·90	+0·58
47·0	−1·08	Sharp *b*	+47·2	227·0	+1·08
47·0	+1·84	Zuchius	−61·5	227·0	−1·84
47·2	−0·28	Marius B	+15·85	227·2	+0·28
47·20	− ·43	Aristarch	+23·29	227·20	+ ·43
47·3	− ·09	Reiner B	+ 5·15	227·3	+ ·09
47·7	+0·62	Fourier A	−31·8	227·7	−0·62
47·8	−2·39	Anaximander A	+67·3	227·8	+2·39
48·21	+0·86	Drebbel	−40·79	228·21	−0·86
48·5	+1·36	Phocylides A	−53·7	228·5	−1·36
49·0	+1·00	Schikard β γ	−45·0	229·0	−1·00
49·96	+0·25	Billy	−14·00	229·96	−0·25
50·4	− ·20	Marius	+11·45	230·4	+ ·20
50·9	+ ·37	Mersenius B	−20·4	230·9	− ·37
51·0	− ·48	Herodot. M	+25·6	231·0	+ ·48
51·2	+ ·20	Hansteen	−11·5	231·2	− ·20

Sun's co-longitudes

At Sunrise.		Latitude.	At Sunset.	
°			°	
51·4	− ·61	Wollaston *c*	+31·2	231·4 + ·61
51·7	+ ·57	Fourier *α*	−29·7	231·7 − ·57
51·9	− ·39	Herodot. A	+21·2	231·9 + ·39
52·0	+ ·44	Cavendish A	−23·8	232·0 − ·44
52·1	+0·76	Lehmann *α*	−37·4	232·1 −0·76
53·6	−1·10	Repsold *d*	+47·7	233·6 +1·10
54·4	+0·52	Vieta ϑ	−27·6	234·4 −0·52
54·4	−1·64	Pythagoras A	+58·6	234·4 +1·64
54·73	−0·11	Reiner	+ 6·51	234·73 +0·11
54·9	−0·50	Herodot. D	+26·45	234·9 +0·50
55·58	+1·41	Phocylides E	−54·58	235·58 −1·41
56·8	+0·29	Fontana	−16·3	236·8 −0·29
56·83	+ ·64	Fourier B	−32·68	236·83 − ·64
56·8	−0·87	Harding C	+40·95	236·8 +0·87
57·0	+1·06	Schikard *ε*	−46·8	237·0 −1·06
57·6	+0·11	Damoiseau *c*	− 6·0	237·6 −0·11
58·4	− ·43	Herodot C	+23·2	238·4 + ·4
59·4	+ ·25	Sirsalis S	−14·3	239·4 − ·25
59·6	−0·75	Harding B	+36·7	239·6 +0·75
60·0	+1·16	Wargentin	−49·2	240·0 −1·16
60·2	+0·37	Fontana A	−20·4	240·2 −0·37
61·61	−1·97	Pythagoras	+63·06	241·61 +1·97
62·0	+0·12	Damoiseau D	− 6·8	242·0 −0·12
62·3	− ·18	Galileo	+10·2	242·3 + ·18
62·5	+0·01	Lohrmann A	− 0·75	242·5 −0·01
63·0	−1·33	Oenopides A	+53·1	243·0 +1·33
63·50	+0·45	Byrgius A	−24·38	243·50 −0·45
65·1	− ·04	Hevel B	+ 2·3	245·1 + ·04
65·5	+ ·69	Piazzi Γ	−34·7	245·5 − ·69
65·81	− ·38	Seleucus	+20·91	245·81 + ·38
66·67	+ ·30	Crüger	−16·77	246·67 − ·30
67·0	− ·11	Cavalerius A	+ 6·2	247·0 + ·11
67·0	+ ·22	Rocca B	−12·4	247·0 − ·22
67·08	− ·61	Lichtenberg	+31·42	247·08 + ·61
67·7	+ ·61	Lagrange A	−31·6	247·7 − ·61
67·9	− ·49	Briggs	+26·15	247·9 + ·49
69·3	+ ·04	Grimaldi B	− 2·4	249·3 − ·04
69·4	+ ·19	Rocca C	−10·95	249·4 − ·19
70·45	+ ·37	Eichstädt B	−20·52	250·45 + ·37
70·5	− ·43	Seleucus B	+23·4	250·5 + ·43
70·87	− ·94	Harding	+43·14	250·87 + ·94
70·89	+0·09	Grimaldi A	− 4·91	250·89 −0·09
72·5	−1·21	Repsold A	+50·4	252·5 +1·21

Sun's co-longitudes At Sunrise.		Latitude.		At Sunset.	
°			°	°	
73·0	−0·26	Cardanus *b*	+14·7	253·0	+0·26
75·0	− ·04	Riccioli B	+ 2·1	255·0	+ ·04
76·2	−0·84	Harding A	+40·1	256·2	+0·84
77·0	−1·82	Cleostratus A	+61·25	257·0	+1·82
77·2	−1·54	Xenophanes A	+57·0	257·2	+1·54
77·29	+0·40	Eichstädt	−21·65	257·29	−0·40
77·54	−0·14	Olbers	+ 7·92	257·54	+0·14

Selenographical Colong. and Latitude of the Point on the Moon's Surface, which has the

Gr. Midnight. 1873.	Sun's Centre in the Zenith. Colong.	Lat.	Earth's Centre in the Zenith. Colong.	Lat.	Greatest Geocentric Libration. Amount.	Direction.
	°	°	°	°	°	
Jan. 31	310·90	−1·45	84·53	+5·79	7·96	46·8 n.p. quadrant.
Feb. 1	323·08	1·46	83·30	4·84	8·26	36·0 „
2	335·26	−1·47	82·57	+3·62	8·26	26·1 „
3	347·43	1·48	82·32	2·24	8·00	16·3 „
4	359·60	1·49	82·51	+0·79	7·53	6·0 n.p.
5	11·76	1·50	83·03	−0·67	7·00	5·5 s.p.
6	23·91	1·51	83·80	2·06	6·53	18·4 „
7	36·06	1·52	84·78	3·33	6·19	32·6 „
8	48·20	1·53	86·07	4·42	5·92	48·4 „
9	60·34	−1·53	87·31	−5·34	5·98	63·3 „
10	72·47	1·54	88·58	6·00	6·16	76·8 „
11	84·61	1·54	89·85	6·40	6·40	88·7 s.p.
12	96·75	1·54	91·12	6·52	6·62	80·3 s f.
13	108·88	1·55	92·32	6·36	6·77	70·0 „
14	121·02	1·55	93·55	5·91	6·89	59·1 „
15	133·16	1·55	94·68	5·20	6·99	48·1 „
16	145·31	−1·54	95·71	−4·25	7·11	36·8 „
17	157·46	1·54	96·59	3·09	7·28	25·2 „
18	169·62	1·54	97·26	1·76	7·47	13·6 „
19	181·79	1·53	97·65	−0·30	7·66	2·3 s.f.
20	193·96	−1·53	97·69	+1·20	7·78	8·9 n.f.
Mar. 1	303·74	−1·49	83·80	+3·88	7·31	32·1 n.p.
2	315·94	−1·48	82·90	+2·46	7·54	19·2 „
3	328·13	1·48	82·51	+0·96	7·55	7·3 n.p.
4	340·32	1·48	82·59	−0·55	7·43	4·3 s.p.
5	352·50	1·47	83·08	1·99	7·20	16·1 „
6	4·67	1·46	83·88	3·30	6·95	28·4 „
7	16·84	1·46	84·93	4·42	6·72	41·2 „

Gr. Midnight. 1873.	Sun's Centre in the Zenith. Colong.	Lat.	Earth's Centre in the Zenith. Colong.	Lat.	Greatest Geocentric Libration. Amount.	Direction.
	°	°	°	°	°	
Mar. 8	29·01	1·45	86·12	5·34	6·60	54·1 „
9	41·17	−1·44	87·40	−6·02	6·56	66·7 „
10	53·32	1·43	88·69	6·43	6·56	78·5 „
11	65·47	1·42	89·98	6·57	6·57	89·8 s. p.
12	77·63	1·41	91·21	6·42	6·53	79·4 s. f.
13	89·78	1·39	92·37	5·99	6·44	68·5 „
14	101·93	1·38	93·44	5·28	6·30	56·9 „
15	114·08	1·36	94·41	4·33	6·18	44·6 „
16	126·24	−1·35	95·27	−3·16	6·14	31·0 „
17	138·40	1·33	95·97	1·83	6·23	16·8 „
18	150·56	1·31	96·49	−0·38	6·50	3·4 s. f.
19	162·73	1·30	96·78	+1·12	6·87	9·4 n. f.
20	174·91	1·28	96·78	2·59	7·26	21·0 „
21	187·09	1·26	96·43	3·95	7·54	31·7 „
22	199·28	−1·24	95·72	+5·12	7·67	42·0 n. f.
30	297·00	−1·11	83·87	+1·40	6·29	12·9 n. p.
31	309·22	1·09	83·41	−0·21	6·59	1·8 s. p.
Apr. 1	321·43	1·08	83·39	1·74	6·83	14·8 „
2	333·63	1·06	83·77	3·14	6·97	26·8 „
3	345·83	1·04	84·49	4·35	7·02	38·4 „
4	358·03	1·02	85·46	5·33	7·01	49·6 „
5	10·22	1·00	86·61	6·06	6·94	60·9 „
6	22·40	−0·98	87·86	−6·52	6·86	71·9 „
7	34·58	0·96	89·15	6·70	6·75	82·8 s. p.
8	46·76	0·94	90·40	6·60	6·61	86·5 s. f.
9	58·93	0·92	91·58	6·20	6·39	75·8 „
10	71·10	0·89	92·65	5·53	6·13	64·5
11	83·27	0·87	93·58	4·59	5·82	52·1 „
12	95·44	0·84	94·35	3·42	5·53	38·2 „
13	107·60	−0·81	94·95	−2·07	5·36	22·7 „
14	119·77	0·79	95·35	−0·59	5·38	6·3 s. f.
15	131·95	0·76	95·56	+0·94	5·64	9·6 n. f.
16	144·13	0·73	95·55	2·45	6·07	23·9 „
17	156·31	0·70	95·31	3·85	6·56	36·0 „
18	168·50	0·68	94·82	5·06	6·98	46·5 „
19	180·70	0·65	54·07	5·99	7·24	55·9 „
20	192·90	−0·62	93·08	+6·58	7·26	85·0 „
21	205·11	−0·60	91·88	+6·77	7·03	74·6 n. f.

Colong. = 90° − λ.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the Year 1872.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day of Obs. 1872.	Phenomenon.	Telescope.*	Moon's Limb.	Mean Solar Time. h m s	Observer.
Feb. 21	Disapp. of γ Cancri	G. Eq.	Dark	13 29 5·6	J C
(*a*)	Reapp. of γ Cancri	„	Bright	14 30 55·3	„
Apr. 13 (*b*)	„ 5 Geminorum	Altaz.	„	8 6 23·1	C
May 19	Disapp. of 65 Virginis	E. Eq.	Dark	9 15 26·4	J C
	„ „	Altaz.	„	9 15 26·8	E
	„ 66 Virginis	E. Eq.	„	10 7 54·1	J C
22	„ ω^2 Scorpii	„	Bright	9 53 13·9	C
	Reapp. of ω^2 Scorpii	„	„	10 59 48·6	„
July 16 (*c*)	Disapp. of Piazzi XVI-10	Altaz.	Dark	9 41 22·9	„
22 (*d*)	Reapp. of τ^1 Aquarii	„	„	15 37 13·5	J C
(*e*)	Disapp. of τ^2 Aquarii	„	Bright	15 55 52·4	„
Aug. 15	Reapp. of σ Sagittarii	G. E.	„	8 53 33·8	„
Sep. 15	Disapp. of τ^1 Aquarii	Altaz.	Dark	11 29 27·7	C
	„ τ^2 Aquarii	„	„	12 45 33·5	„
24	„ ε Geminorum	E. Eq.	Bright	12 27 21·5	„
	Reapp. of ε Geminorum	„	Dark	13 27 5·8	„
Oct. 11	Disapp. of 35 Capricorni	„	„	10 25 58·0	L
14	„ 33 Piscium	G. Eq.	„	5 53 32·5	„
Dec. 9	„ *f* Piscium	E. Eq.	„	7 16 26·6	E

(*a*) The star was faint from haze; the observed time is, however, within a second.

(*b*) Not good; the star was sensibly separated from the Moon's limb when first seen.

(*c*) Star very faint.

(*d*) Observation satisfactory.

(*e*) The time recorded above is uncertain to 2^s; the star being very faint and the Moon's limb tremulous.

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* The clear aperture of the object-glass of the Great Equatoreal is $12\frac{3}{4}$ inches, of the East Equatoreal, 6·7 inches, and of the Altazimuth $3\frac{3}{4}$ inches.

Phenomena of Jupiter's Satellites.

Day of Obs. 1872.	Satellite.	Phenomenon.	Telescope.	Mean Solar Time of Observation. h m s	Mean Solar Time from N. A. h m s	Observer.
Jan. 3	II.	Ecl. disapp.	E. Eq.	6 29 13·4	6 29 16·5	G
	II.	Occ. reap. bisec.	„	9 57 53·5	9 59	„
	II.	„ last cont.	„	9 59 38·3		
5	III.	Tr. egr. last cont.	„	19 2 19·3	19 6	C
6	I.	Ecl. disapp.	„	12 42 22·4	12 42 4·9	„
7	IV.	„	„	17 44 19·2	17 39 9·3	J C
8 (*a*)	I.	„	„	7 10 15·7	7 10 33·1	L
16	III.	Occ. dis. bisec.	Altaz.	8 32 33·0	8 29	C
24 (*b*)	I.	Ecl. reapp.	E. Eq.	7 42 14·5	7 42 10·3	„
	IV.	Occ. dis. first cont.	„	9 20 3·4	9 20	„
	IV.	„ last cont.	„	9 25 2·6		
(*c*)	IV.	Ecl. reapp.	G. Eq.	15 39 43·9	15 42 51·2	H C
31 (*d*)	I.	„	„	9 37 2·0	9 36 42·7	„
Feb. 21 (*e*)	III.	„	„	8 0 46·3	8 1 53·3	J C
Mar. 6	III.	Occ. dis. first cont.	E. Eq.	8 5 11·6		
(*f*)	III.	„ bisec.	„	8 8 26·1	8 16	L
	III.	„ last cont.	„	8 13 50·2		
(*g*)	III.	Ecl. disapp.	„	12 40 5·8	12 38 12·4	„
8	I.	Occ. dis. first cont.	„	10 13 33·7		
	I.	„ bisec.	„	10 16 23·2	10 17	P
	I.	„ last cont.	„	10 19 7·8		
9	I.	Tr. ing. first cont.	„	7 36 58·7		
	I.	„ bisec.	„	7 38 28·5	7 37	E
	I.	„ last cont.	„	7 40 58·1		
	I.	Tr. egr. bisec.	„	9 56 6·0	9 56	„
	I.	„ last cont.	„	9 59 5·5		
10	I.	Ecl. reap.	G. Eq.	8 8 32·5	8 9 7·5	C
13	III.	Occ. dis. first cont.	E. Eq	11 50 44·2		
(*h*)	III.	„ bisec.	„	11 53 43·7	11 55	J
	III.	„ last cont.	„	11 56 13·3		

(*a*) The diminution of brightness was first noticed $1^m\ 15^s$ before the time recorded above.

(*b*) Satellite faint, *Jupiter* being near the Moon. It required more than three minutes to attain its full brightness.

(*c*) The satellite was not at its full brightness till eight minutes after it was first seen.

(*d*) Observation good; full brightness about $1^m\ 30^s$ after the time recorded above.

(*e*) Satellite at full brightness $7^m\ 29^s$ after the time recorded above.

(*f*) Image of *Jupiter* not good; it was difficult to estimate the exact time of bisection.

(*g*) The first diminution of light $3^m\ 29^s$ before the time recorded above.

(*h*) Observed time of bisection uncertain; image of satellite very bad.

Day of Obs. 1872.	Satellite.	Phenomena.		Mean Solar Time of Observation. h m s	Mean Solar Time from N. A. h m s	Obser-ver.
Mar. 16 (*i*)	I.	Tr. ingr. bisec.	G. Eq.	9 30 23·1	9 27	C
	I.	„ last cont.	„	9 31 42·8		
24 (*k*)	I.	Ecl. reapp.	E. Eq.	12 0 56·4	11 59 50·1	„
31	IV.	Ecl. disapp.	G. Eq.	11 58 59·0	11 54 3·4	W C
	III.	Tr. egr. bisec.	„	12 50 0·6	12 54	„
	III.	„ last cont.	„	12 53 30·0		
Apr. 8 (*l*)	II.	Ecl. reapp.	Altaz.	8 26 46·9	8 25 49·3	L
9	I.	„	E. Eq.	10 20 0·3	10 19 34·8	E
11 (*m*)	III.	Ecl. disapp.	G. Eq.	8 41 5·7	8 38 19·0	J C
15	II.	Ecl. reapp.	Altaz.	11 0 4·5	11 1 5·9	C
16 (*n*)	I.	„	G. Eq.	12 14 53·5	12 15 4·8	J C
17 (*o*)	IV.	„	„	10 19 50·6	10 22 32·6	L
May 1 (*p*)	I.	Tr. ingr. first cont.	E. Eq.	9 54 50·6	9 52	C
Oct. 18 (*q*)	IV.	Ecl. reapp.	G. Eq.	17 4 12·2	17 2 7·0	H C
Nov. 19	III.	Occ. dis. first cont	„	17 6 34·3	17 6	C
	III.	„ last cont.	„	17 12 3·4		
26	III.	Ecl. disapp.	„	16 5 18·4	16 1 52·1	H C
Dec. 7 (*r*)	III.	Tr. egr. first cont.	„	18 6 56·8	18 19	„
	III.	„ bisec.	„	18 11 56·0		
	III.	„ last cont.	„	18 17 55·0		
	IV.	Ecl. disapp.	„	18 14 53·5	18 11 59·0	„
	II.	Tr. ingr. first cont.	„	18 28 53·2	18 38	„
	II.	„ bisec.	„	18 32 22·7		
	II.	„ last cont.	„	18 35 52·1		
25 (*s*)	III.	Ecl. reapp.	„	11 28 36·3	11 26 35·0	W C
	I.	Ecl. disapp.	„	12 1 41·9	12 1 8·9	„
	III.	Occ. dis. first cont.	„	12 4 0·5	12 3	„
	III.	„ bisec.	„	12 6 0·2		
	III.	„ last cont.	„	12 9 29·6		

(*i*) The satellite appeared intensely white, and very much brighter than *Jupiter*.

(*k*) Tremulous.

(*l*) Observation unsatisfactory; ill-defined image; the full brightness was attained in two minutes.

(*m*) Satellite apparently dichotomized six minutes before the time recorded above; light clouds passing.

(*n*) Tremulous; light clouds about *Jupiter*; full brightness $2^m\ 33^s$ after the time recorded above.

(*o*) Full brightness $5^m\ 38^s$ after the time recorded above.

(*p*) Bad image.

(*q*) The satellite did not seem to be at its usual brightness till about nine minutes after its first appearance.

(*r*) *Jupiter* tremulous at all the observations.

(*s*) Full brightness between five and six minutes after the time recorded above.

The initials W C, E, C, L, J C, H C, P, J, and G, are those of MM. Christie, Ellis, Criswick, Lynn, Carpenter, H. J. Carpenter, Potts, Jenkins, and Goldney.

Note on Projections illustrating the presentation of the Planet Mars during the year 1873, and showing the Martial Lands and Seas which will be in view at different Epochs. By Richard A. Proctor, B.A. (Cambridge).

Although the opposition of the planet *Mars* during the year 1873 is not a particularly favourable one, the planet being nearer the aphelion than the perihelion of its orbit, yet there are some circumstances which render it particularly desirable that the planet should be carefully studied on this occasion.

In the first place, the planet will be passing through the autumn months of its northern hemisphere, that is, the months between Martial midsummer and the autumnal equinox. On this account the opportunity is a favourable one for studying the north-polar region of the planet, the errors there being probably much reduced in extent, and presumably the true place of the pole more satisfactorily indicated than usual.

Then, secondly, the northern half of the planet is now fairly turned towards the Earth, and is likely to be clear of Martial clouds and mists, insomuch that the shape of the lands and seas on this the least-known half of the planet can now be satisfactorily determined.

On this account I have thought it desirable to prepare the accompanying table and diagrams as a guide to intending observers of the planet during the opposition of 1873.

The diameters and the illuminated portion of the disk, in the plate, have been taken directly from the *Nautical Almanac*.

The elements on which the determination of the axial position of *Mars* has been based are those given in No. 858 of the *Astronomische Nachrichten*, in a paper by Dr. Oudemans upon the observations made by Bessel with the Königsberg heliometer between the years 1830 and 1837. He gives (as quoted in a note by Mr. Hind in 1867),

Longitude of pole of *Mars* .	349°	1′	for ecliptic.
Latitude	61	9	

Assuming these numbers to apply to 1834·0, we find,

Longitude of ascending node of Equator of *Mars* upon his orbit (λ′)	80° 50′·4
Obliquity of Martial ecliptic (I′) . . .	27 16·5

And hence

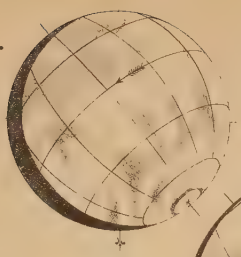
Ascending node of Equator of *Mars* on the Earth's Equator (N)	47° 33′·9
Inclination (I)	39 55·6

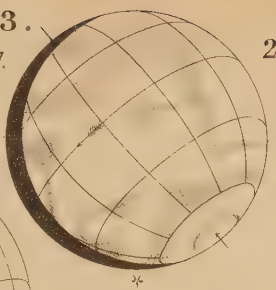
For $1873{\cdot}0 + t$ these values give

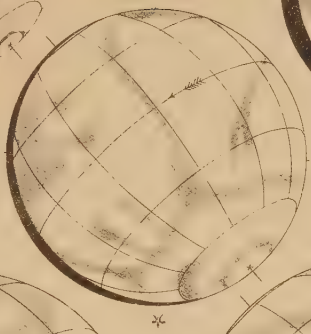
$$N = 47^\circ\ 53' + 0{\cdot}50\,t$$
$$I = 39\ 43 - 0{\cdot}25\,t.$$

MARS IN 1873.

Opposition, Apr. 27.

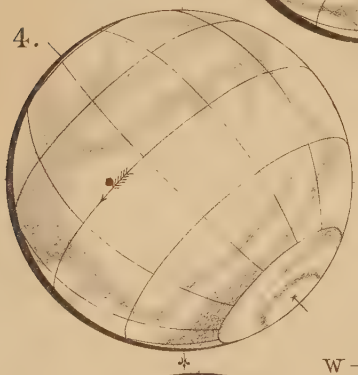


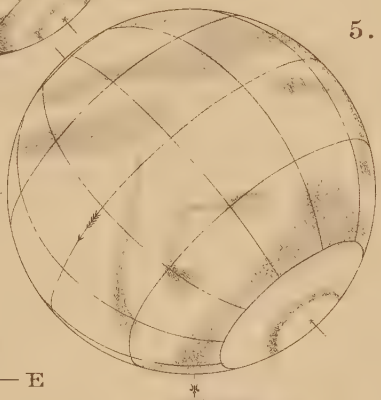


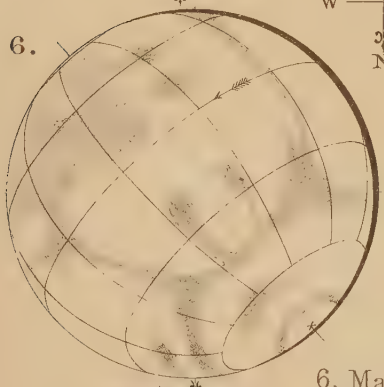


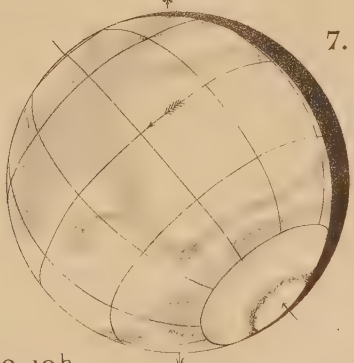
1. Feb. 26, 12^{h}.
2. Mar. 13, 12^{h}.
3. Mar. 28, 12^{h}.
4. Apr. 12, 12^{h}.

5. Apr. 27. 12^{h}. (Opposition)

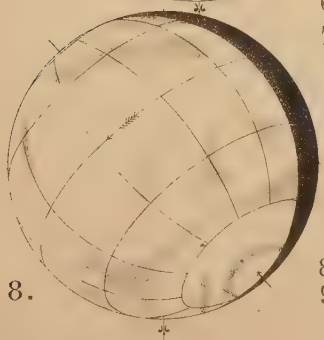


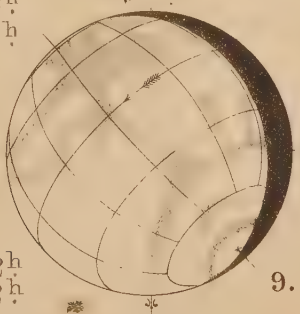






6. May 12. 12^{h}.
7. May 27. 12^{h}.





8. June 11, 12^{h}.
9. June 26, 12^{h}.

R.A. PROCTOR, DEL. MALBY & SONS, LITH.

I have adopted these values in the computation of p and l in the accompanying table; p being the apparent inclination of the axis of *Mars* to the circle of declination, and l the elevation of the Earth above the equator of the planet; using the following formulæ:—

Let α be the geocentric Right Ascension of *Mars*
δ ,, Declination ,,

and Q an auxiliary angle such that

$$\tan Q = \tan i \,.\, \sin (\alpha - N)$$

then

$$\tan p = -\frac{\sin Q}{\cos (Q - \delta)} \cot (\alpha - N)$$

and

$$\tan l = \tan (Q - \delta) \cos p.*$$

Moreover, if l' be the elevation of the Sun above the plane of the ring, λ the heliocentric longitude of *Mars*, then, with sufficient approximation,

$$\sin l' = \sin (\lambda - \lambda') \sin I'.\dagger$$

---

* These formulæ are given by Mr. Hind in the note referred to above, and are the same as are used in the *Nautical Almanac* for determining the position and phase of *Saturn's* ring. (They are given in full, with others, among the explanations of the tables in my Treatise on *Saturn*.) But in Mr. Hind's note, by an inadvertency, the denominator in the expression for $\tan p$ is written $\sin (Q - \delta)$. The following formulæ can be used, if preferred:—

$$\cos l \,.\, \sin p = -\sin I \,.\, \cos (\alpha - N)$$
$$\cos l \,.\, \cos p = \sin I \,.\, \sin (\alpha - N) \sin \delta + \cos I \cos \delta$$
$$\sin l = \sin I \,.\, \sin (\alpha - N) \cos \delta - \cos I \sin \delta.$$

† Strictly speaking, formulæ corresponding to those given at p. 229 of my treatise on *Saturn* should be employed, viz., putting

β = *Mars'* heliocentric latitude,

ν = longitude of ascending node of *Mars'* orbit on ecliptic,

and Ω' = arc from ascending node of *Mars'* orbit on ecliptic to ascending node of *Mars'* equator on his orbit.

Then assuming

$$\cos \Psi = \cos (\lambda - \nu) \cos \beta$$

we have

$$\sin l' = \sin (\Psi - \Omega') \sin I'.$$

Date. Greenwich. Noon. 1873.	*p*.	*l*.	*l'*.	$\lambda - \lambda'$.
Feb. 26	41° 4′ W.	15° 7′ N.	25° 47′ N.	108° 21′
Mar. 13	41 3	14 7	24 29	115 12
28	41 4	14 15	22 49	122 10
April 12	41 10	15 34	20 47	129 15
27	41 0	17 57	18 23	136 29
May 12	40 31	20 30	15 40	143 53
27	40 2	22 18	12 30	151 27
June 11	40 2	22 59	9 21	159 13
26	40 33	22 36	5 50	167 11

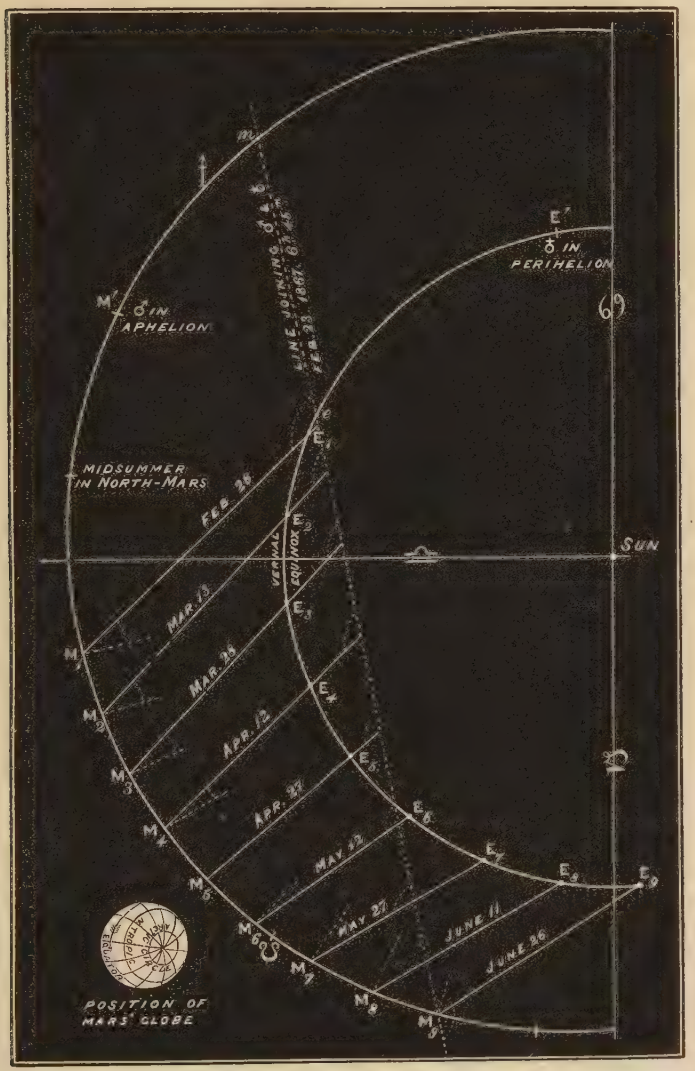
It will be seen that the value of *p* changes very little during the four months. Usually *p* changes largely. Thus in the opposition-period of 1866–7, *p* ranged in value between 9° 50′ and 21° 52′. The reason of the approach to constancy in the value of *p* during the present opposition is readily seen on a consideration of the accompanying figure, which shows the varying position of the line joining the Earth and *Mars*. This needs no explanation, so far as those are concerned for whom this paper is specially intended.*

It will furthermore be noticed that while *l'* continually diminishes, as *Mars* passes from the neighbourhood of his midsummer place to that of his autumn place (for his northern hemisphere), *l* first diminishes, afterwards increases, and then diminishes again. This also is explained by the figure. It will be seen, also, how in the illustrative plate the boundary between the illuminated and the dark parts of *Mars*' disk accords with the values of *l* and *l'*.

The woodcut shows the method by which the areographic features of *Mars* for the epochs indicated in the plate have been determined from an observation of *Mars* made on February 23, 1867, at $6^h\ 45^m$ P.M. by Mr. Browning. (The hour in each case is midnight, Greenwich mean time.) The picture of *Mars* then obtained is shown in Plate II. of my *Essays on Astronomy*. Between the date of that observation and April 27, 1873, midnight, there is an interval of 194850900 seconds. Taking the rotation period of *Mars* as 88642·73 seconds, I find that the number of rotations of *Mars* amounts to 2198 + a rotation through 57°. I take the Kaiser Sea as 21° from the central meridian in Mr. Browning's picture (approaching the meridian), and the line joining the Earth and *Mars* on April 27 makes an angle of about 117° with the corresponding line on February 23, 1867. This obviously amounts to setting *Mars* 117° *back* in rotation. Thus, instead of 2198 Rot. + 57°, we have 2198 Rot. — 60°, or the Kaiser Sea 81° from the central meridian, instead of 21° as on

* In a paper which will appear in the *Quarterly Journal of Science* for April, this and the other relations illustrated by the figure will be found fully explained.

Feb. 23, 1867, at $6^h\ 45^m$. The picture of *Mars* for April 27, No. 5 of the plate, corresponds with this result. The others have been



Illustrating the motions of the *Earth* and *Mars* during, March, April, May, and June, 1873.

obtained from similar considerations, account being taken in every case of the changing bearing of *Mars* from the Earth.

Markings observed on Uranus. By W. Buffham, Esq.

The writer, having observed certain appearances on this planet — usually deemed intractable to ordinary means — has complied with the suggestion of two eminent Fellows of the Royal Astronomical Society to ask permission to lay before it the results of his observations, accompanied by six sketches.* The telescope employed is a 9-inch With-Browning reflector, with achromatic eye-pieces.

1870, Jan. 25, at 11^h to 12^h, in clear and tolerably steady air. —Power 132 showed that the disk was not uniform. With powers 212 and 320 two round bright spots were perceived, not quite crossing the centre, but a little nearer the eastern side of the planet, the position-angle of a line passing through their centres being about 20° and 200°. Ellipticity of *Uranus* seemed obvious, the major axis lying parallel to the line of the spots. It is possible that irradiation may have been concerned in producing this impression. The limb of the western half of the disk gradually deepened from the centre to bluish near the limb, and the border all round was fainter than the spots. In the hours of observation I thought the southern spot had become less defined on the side nearest the south, and both rather nearer that limb of the planet.

Jan. 27, 10^h to $10\frac{1}{2}^h$.—Some fog, and definition not so good; but the appearance of the spots was almost exactly as on the 25th.

Jan. 29, $8\frac{1}{2}^h$.—Not very clear. I thought the eastern side a little brighter, but not certain. Same at $10\frac{1}{2}^h$.

March 19, $8\frac{1}{4}^h$ to $8\frac{3}{4}^h$.—Definition not very good. Glimpses of a light streak in a similar position to the two spots first seen. At $10\frac{1}{2}^h$ I thought there were traces of the spots. Ellipticity again noticed, and in the same direction.

April 1, 8^h.—A luminous zone certainly seen in the usual position; not of uniform breadth, but it bulged out in places. At 9^h and 10^h the latter feature less evident.

April 4, $8\frac{1}{2}^h$ to $9\frac{1}{4}^h$.—Clearer air. The bright zone plainer than on the 1st. One swelling suspected. At 11^h a similar appearance.

April 6, 9^h to 10^h.—Brighter portions of the zone more certainly perceived. The preceding side of the zone was darker than the general ground of the disk.

April 8 [time not noted].—Glimpses of the zone, but half-moon a few degrees distant.

Bad weather and other hindrances prevented further observations until—

1871, Dec. 27, $9\frac{1}{2}^h$ to 10^h.—Persuaded that a brighter region crossed the disk. At times it appeared to take the form of a bright speck towards the south, with a less obvious portion towards the north, the general direction of the whole being from

* These were exhibited at the Meeting.

N. to S. Western side again observed to be of a deeper tint. Circumstances unfavourable to a rigid scrutiny.

1872, Feb. 20, $10\frac{1}{2}^h$ to $11\frac{1}{2}^h$.—Could not resist an impression that the part near S.E. limb was brighter than the rest, but the disk was too unsteady to make out definitely its form.

Feb. 21, 9^h.—Too unsteady to make out more than the southern side a little brighter.

March 6, $9\frac{1}{2}^h$ to 10^h.—In fine moments brighter portions S. and S.W. could be seen, but without well-marked form. N. side of the disk bluer.

March 9, $8\frac{1}{2}^h$ to 9^h.—Clear, and pretty steady definition. With powers 212 and 320 the S.E. side is certainly brighter than the general ground. There is also a dark line near the centre, running N. and S. At $10\frac{1}{2}^h$ to 11^h, the disk is more uniform in tint; the dark line not seen; near the S. limb slightly brighter than the rest.

At $11\frac{3}{4}^h$ to 12^h.—Nearly uniform. I think there is still a small brighter part on south preceding limb.

The observations of the last night seem to afford evidence of the rotation of *Uranus* in a similar direction to that indicated by the luminous spots and zone observed in 1870. If this be so, the plane of the planet's equator is not coincident with the plane of the orbits of his satellites. Nor need we be surprised at this departure from the general rule, where such an anomalous inclination exists. In singular confirmation of this (apparently) is Mr. Lassell's observation of 1862, Jan. 29, where he says, "I received an *impression*, which I am unable to render certain, of an equatorial dark belt, and of an ellipticity of form." (The direction is not given.) This would be remarkable if the equator of the planet coincided with the plane of the orbits of the satellites, which were at that time nearly square to the visual line. Assuming, however, the equator to have been near the node in Jan. 1870 (which seems indicated by my earlier observations), a rough projection will show that in 1862 the equator would be visible, though lying towards the western side, and ellipticity might therefore be perceived. The apparent discrepancy (so often quoted) between the results of Mädler and O. Struve is by this assumption reduced, if not entirely removed; for at the epoch of the latter observer (about 1850, I believe) the planet would be near its polar projection in 1849; while in 1842, when Mädler measured *Uranus*, it would be sufficiently distant to allow the equatorial protuberance to manifest itself. Referring once more to Mr. Lassell's observations on this point, he states that in 1852 he could not satisfy himself that there was any sensible ellipticity.

As to the period, anything more than a suggestion would seem to be mere assumption. But taking the appearances seen 1870, Jan. 25 and 27, as indicating the same face of the planet, together with the movement observed 1872, March 9, during

about $3\frac{1}{2}$ hours, it will hardly be far from the truth to suppose *Uranus* rotates in a period of about twelve hours.

Gathering up these results as the merest approximations, we have,—

	±
Time of rotation	12 hours.
Inclination of equator ...	80°.
Long. of ascending node ...	110°.

Movement direct.

2 *Princes Terrace, Bonner's Road, Victoria Park, E.,*
Nov. 21, 1872.

On an Error in the Right Ascension of No. 3735 *of Groombridge's Catalogue of Stars.* By Edwin Dunkin, Esq.

The right ascension of this star as given in the Groombridge Catalogue is derived from eleven transits, and on this account it might be considered to be a well-determined value. The Astronomer Royal's attention has, however, been lately directed by M. Argelander to a disagreement between this value and that contained in several other catalogues, the difference being far too great and irregular to be accounted for by any proper motion of the star. From a comparison of Groombridge's R.A. for 1810, January 1, with the R.A. given in the catalogues of Fedorenko's Lalande, Armagh, Oeltzen's Argelander, the Radcliffe First Catalogue, and Greenwich (1872), reduced to the same epoch, the mean R.A. of Groombridge appears to be about three seconds too small.

At the request of the Astronomer Royal, I have made a searching examination of the original calculations of the Groombridge catalogue * with the object of discovering, if possible, whether any constant error affecting each observation had been inadvertently committed in the reductions. Unfortunately, in several instances, the calculations intervening between the original observations have never been found, and for one preliminary catalogue of about 900 stars, marked A, this is notably the case. This catalogue contains seven observations, made in 1809, from September 6 to October 8, out of the total number of eleven. The remaining four, made in 1812, are included in another preliminary catalogue, marked D, formed from later observations than those in A.

As none of the calculations intervening between the " Transit

* The original manuscript observations and calculations have been deposited in the Society's Rooms since the publication of Groombridge's catalogue in 1838.

Book" and A can be found, and as no record is made in the catalogue of the date of the observations, some trouble was experienced in finding the original separate transits. This difficulty, was increased by Groombridge naming the star *Cepheus Bode* 197 in A, and *Cepheus Bode* 204 *p* in D. All the transits in A, except one, were observed over the central wire only, and assuming that the instrumental adjustments were good, of which there is no evidence to the contrary, the work appears to have been accurately done. So far as the reduction to apparent R.A., the check is easily made in the "Transit Book." The only part which required an independent calculation, owing to the absence of the original work, was the reduction to mean R.A. 1807, January 0, this being the epoch to which Groombridge himself referred his right ascensions in catalogue A. The R.A. given in this catalogue reduced to 1810, January 1, is $22^h\ 10^m\ 26^s{\cdot}72$, and although too small, it is correctly reduced from the original transits.

With respect to the four transits from which the R.A. in catalogue D has been obtained, the case is very different; but, fortunately, we have a sure means of testing the accuracy of the reductions of these four transits by a comparison of the separate results for R.A. with those of a neighbouring star, differing from 3735 by less than 1′ in N.P.D. From 1812, October 29, to November 22, this comparison star, named *Cepheus Bode* 204, and now known as *Groombridge* 3756, was observed on several occasions on the same evenings as 3735. I resolved to make, therefore, a fresh reduction of all the transits of the two stars, which might possibly give some clue to the cause of the error which evidently affects Groombridge's results.

As nearly all the transits used in the formation of Catalogue A were observed only over the central wire, no error could arise from a wrong reduction to the meridian; but as those used in forming catalogue D were never observed over the central wire, it occurred to me that whatever may have been the error, the source of it, so far as these four transits are concerned, would be found here. I therefore calculated the following equatoreal corrections to be applied to each wire for reduction to the central wire, from twenty-five complete transits of stars observed for clock-error about the same time :—

		s
Wire I.	=	+ 50·74
II.	=	+ 25·29
IV.	=	− 25·49
V.	=	− 50·55

The following table contains the separate results for each star, the mean R.A. being reduced to 1810, January 1 :—

Day of Obs. 1812	Groombridge 3735. New R.A. h m s	R.A. from MSS. s	Groombridge 3756. New R.A. h m s	R.A. from MSS. s
Oct. 29			22 15 57·92	58·03
31	22 10 28·11	23·11	57·90	57·83
Nov. 7			58·55	58·41
15	28·47	23·61	57·14	57·32
21	28·35	24·80	58·43	58·37
22	28·17	24·62	58·61	58·54
Mean	22 10 28·28	24·04	22 15 58·09	58·08

On reducing the transits at each wire separately to the central wire, the observed time at the fourth wire on November 15, in the transit 3735, appears to be some seconds in error. I have therefore not included it.

The difference between the newly-computed R.A. of 3735 and that taken from D is no less than $4^{s}\cdot24$, while the new and old results for the comparison star are sensibly the same. This is a sufficient proof that the error originated not from defective values of the intervals, as then the results for both stars would have been similarly affected, but from an accidental slip made in the reductions of 3735. The only suggestion I can make is that Groombridge, in whose handwriting the "Transit Book" appears to be, adopted an erroneous N.P.D. in the reduction of the observed transits to the meridian, and that, instead of using 14° 29′, the correct N.P.D., he made the reduction with N.P.D. 14° 9′. Assuming this to be the cause of the error, I have reduced each transit of 3735 to the meridian with the erroneous N.P.D., the separate results for R.A. of which are compared below with the corresponding R.A. taken from the manuscript collection of results:—

Mean R.A. 1810, January 1.

Day of Obs.	New R.A. using N.P.D. 14°·9′ h m s	R.A. from MSS. h m s
1812, Oct. 31	22 10 23·45	22 10 23·11
Nov. 15	23·65	23·61
21	24·84	24·80
22	24·66	24·62
Mean	22 10 24·15	22 10 24·04

The result of my examination of the original calculations is thus successful with respect to the four observations from which the R.A. in catalogue D is obtained. This R.A., as corrected by me, now agrees very closely with the modern determinations. The R.A. in catalogue A, deduced from seven observations, is, however, still about two seconds too small, the cause of which

must remain unexplained; it certainly cannot be found from an inspection of the original manuscripts. But it is proper to remark that there is a considerable discordance between the separate daily results, the seconds of R.A. of the greatest value being $27^{s}\cdot80$, and of the least, $25^{s}\cdot47$, or a range of $2^{s}\cdot33$. The following table exhibits the mean R.A. taken from several catalogues and reduced to 1810, January 1 :—

Catalogue.	Mean R.A. 1810, Jan. 1.	Epoch of Catalogue.
	h m s	
Fedorenko's Lalande ..	22 10 29·49	1790
Groombridge (A) ..	26·72	1807
„ (D) ..	28·28	1812
Armagh ..	28·93	1840
Oeltzen's Argelander ..	28·98	1842
Radcliffe 1st Cat. ..	28·31	1845
Greenwich 1872 ..	28·81	1872

The mean of the R.A. in the two Groombridge Catalogues, A and D, giving a weight to each proportional to the number of observations, is $22^{\circ}\ 10'\ 27''\cdot29$. The R.A. in the published Groombridge Catalogue is $22^{h}\ 10^{m}\ 25^{s}\cdot83$.

Kidbrooke, Blackheath,
December 23, 1872.

On an observed Discordance between the Reading for Zenith-point in the Determinations with the Transit-Circle of the Royal Observatory, Cape of Good Hope. By E. J. Stone, M.A. F.R.S., Her Majesty's Astronomer at the Cape.

The Transit-Circle of the Royal Observatory, Cape of Good Hope, was designed by Sir G. B. Airy, K.C.B. Astronomer Royal.

It is similar in construction and optical power to the magnificent instrument of the Royal Observatory, Greenwich. There are only two points of difference. The handles for moving the instrument are removed from all connexion with the reading-circle, to the opposite side of the central cube; and, in the original construction of the instrument, arrangements were made by the Astronomer Royal for the observation of the collimators through the central cube without the necessity of raising the instrument from its Y's.

Sir G. B. Airy has given a full description of the Greenwich instrument, with detailed plans, in the volumes of *Greenwich Observations*, 1852 and 1867. This appears to render any description of the Cape instrument unnecessary. Soon after taking charge of the Observatory, I had observations of α *Centauri*, β *Centauri*, and α *Eridani*, taken by reflexion and directly.

I made it a rule, that with these observations the runs and nadir-point reading with the reflecting eye-piece should be taken by the same observer. A discrepancy of a very sensible amount, between the zenith-points determined from the star-observations and those determined with the reflecting eye-piece, was apparent. In fact, the zenith-point readings, determined with the reflecting eye-piece, were greater by quite one second of arc than the reading determined from the group of stars. The horizontal flexure of the telescope was first redetermined. It differed by nearly $0''{\cdot}4$ from that in use, which had been determined in 1855; but the effect of this correction would tend to increase the observed discrepancy. The inclination of the wire was carefully examined, but there was no error upon this point. It appeared to me possible that the discordance might be due to imperfect correction for division-errors, connected with some slight deformation of the reading-circle from strains in different positions of the instrument. Some observations of the lengths of arcs, measured under the six principal microscopes and the supplementary microscopes, for the determination of the division-errors, appeared to favour the idea. A complete redetermination of the division-errors to every 5°, and a grouping of residual errors to test this point, was therefore undertaken. The result, however, appeared to prove clearly that the mean reading, with six microscopes, could not be affected from this cause to more than a tenth of a second. The resulting division-errors in the different sets were most accordant; but the observed discrepancy in the zenith-points was but little influenced by their introduction instead of those already in use. The general runs of the old and new determinations were similar, although very sensible differences appeared at certain divisions.

The ground being thus cleared, it appeared probable that this observed discordance must be looked for in an imperfect correction for flexure under the assumed form,—

$$\text{Constant} \times \sin(\text{Zenith Distance.})$$

Some observations of stars by reflexion were then made to the north, for the purpose of a comparison of the results thus obtained with those found from the Southern stars, and from the Nadir observations. The following are the results at present available.

From 143 observations of Southern stars, with mean zenith distance about 25°,—

1. Nadir Reading—South Horiz. Point $= 90° + 1''{\cdot}10$.

From 33 observations of Northern stars, with mean zenith distance about 37°,—

2. Nadir Reading—North Horiz. Point $= 0''{\cdot}77 - 90°$.

The flexure correction employed in the reduction of those observations has been

$$-0{\cdot}26 \sin \text{Z.D. south.}$$

The constant for flexure found in 1871, was $-0''{\cdot}617$. If the true correction for flexure is assumed to be—

$$a \sin z + b \cos z + c \sin 3z,$$

we should find from these data,—

$$\text{True Reading} = \text{Reading of Circle} - 0''{\cdot}376 \sin z + 0''{\cdot}92 \cos z + 0''{\cdot}241 \sin 3z.$$

The value of the coefficient of cos z is so large, that I have endeavoured to control its determination by direct observations. I may mention, that I have carefully tried whether any sensible difference does exist between the nadir-points, determined after moving the instrument in different directions towards the nadir. In the Cape instrument no such discordance appears to exist. There are at the Observatory a theodolite and collimator, with apertures of about an inch and a half. The theodolite telescope does not clear its circle at much greater zenith distances than 150°.

The theodolite and collimator were mounted as opposite telescopes, inclined at angles, 210° Z.D.S. and 30° respectively. The theodolite rested upon a stone slab, across the opening of the transit-circle room. A detached platform was erected for an observer. The collimator was mounted on a wooden frame, resting upon the solid rock; a portion of the observing floor was removed for this purpose. The cross wires of the theodolite were first adjusted to centre wire, free from collimator error, and the horizontal wire of the transit-circle at 30° Z.D.S. The wires of the collimator were then similarly adjusted when the transit-circle was reading 210°. The observer at the theodolite then brought the micrometer wire of this instrument into coincidence with the horizontal wire of the collimator, by vision through the circular apertures of the cube of the transit-circle. When the wires were apparently in coincidence, the object-glass of the Transit-circle was turned upon that of the theodolite, and the instrument clamped, and the readings taken for coincidence of the horizontal wire. The instrument was then turned upon the collimator, and similar readings taken. Finally, as a check, the object-glass was again turned upon the theodolite, which was somewhat exposed, and the readings again taken. If the two sets of readings of the theodolite wire coincidence did not differ much the set was considered satisfactory.

When twenty-one such sets had been made, the theodolite was mounted towards the North, with its telescope at an angle of 150 S. and the collimator was mounted in the pit towards the South, and similar observations were made. Fourteen sets were made in these positions of the instruments.

To avoid the effects of personality as much as possible, the observations at the theodolite and eye-piece of the transit-circle were about equally distributed between me and Mr. G. Maclear. The circle microscopes were read by Mr. Freeman. These observations were continued at favourable opportunities through May 1872.

The results are as follows,—

1st Set. Reading for North Collim. = { That for South Theo. + 1″·86.

2nd Set. Reading for South Collim. = { That for North Theo. + 2″·15.

If we assume, as before, that the flexure is of the form $a \sin z + b \cos z + c \sin 3z$, we should have, since

$$a - c = -0''\cdot617$$

True reading = Reading of circle $-0''\cdot460 \sin z + 1''\cdot15 \cos z + 0''\cdot157 \sin 3z$.

The result, therefore, confirms the existence of the large value of b determined from the discordances between the nadir-point readings.

Unfortunately, the only collimating telescopes which I could mount have very small apertures in comparison with that of the transit-circle, and their focal lengths are too small to bear even the power employed. I cannot altogether regard this determination as satisfactory, but I believe that there can be no doubt about the existence of a large term varying as cos Z D. It may be mentioned that the collimator was independently mounted and dismounted eight times during the experiments. I prefer, however, to trust the numerical determination of the constants to the observations of discordance of the zenith-points; but the number of observations of stars to the north is at present scarcely sufficient for an accurate determination of the coefficients, although I believe it to be abundantly sufficient for a very approximate one. It may be remembered that the Astronomer Royal found that the horizontal flexure of the transit-circle at Greenwich changed sign after the piercing of the cube in 1865, and that this change of sign was accompanied by a change of sign in the R—D. correction of the Observatory. I fear that the astronomical flexure of the telescope must be attributed as partly due to changes in the form of the central cube, or parts of attachment of the object-glass and eye-piece cones, and that the crushing and extending forces of these heavy cones are the cause of the existence of the term depending upon cos Z D.

For the reduction of stars very near to the pole, within 5° observed in 1871, I have reduced all the observations with the zenith-points determined from the observations with the reflecting eye-piece, and have then applied to all the results a correction derived in the usual way as a colatitude correction. But, although such a process is satisfactory for stars near the pole, yet if the discordance between the zenith-points is real, and varies as the zenith-distance of the object observed, it is clear that the colatitude deduced, as above mentioned, need not be the true colatitude, and that the stars near the pole and far from the pole cannot be chained together in one series without an allowance for

the existing discordance. I believe this discordance in the Cape instrument must be due to flexure; but, whatever be its cause, it must be of the utmost importance to keep the discordance well in view, as a check upon assumptions of accuracy which are unobtainable with the instrument, and also in the hope that the cause may be discovered and removed. It is a discordance easily disguised or lost sight of by the use of zenith-point corrections from nadir eye-piece alone.

I cannot, therefore, but regard as most important the clear manner in which my old master, Airy, has insisted upon keeping this point prominently in view, in spite of its having been often regarded, as in one sense it of course is, as an indication of imperfection in the instrument used or the methods adopted. It appears, however, to me that it would be better, in the face of such a discordance, to reduce the observations with nadir-point determinations with the reflecting eye-piece, and to observe stars by reflexion, to detect the law of the discrepancy and the numerical coefficients of its expression. The necessary corrections could then be easily applied to the mean results, and this method would allow of modifications being introduced in the results as further light was thrown upon this subject, or more accurate determinations of the coefficient of an assumed law were obtained.

1872, *November* 2.

Summary of Sun-spot Observations made at the Kew Observatory during 1872. By Warren De La Rue, Esq., F.R.S.

Months.	Days of Observation.	Numbers given to the New Groups in the Kew Catalogue.	Number of New Groups.	Days without Spots.
January	10	1800 to 1820	21	0
February	14	1821 ,, 1843	23	0
March	10	1844 ,, 1850	7	0
April	15	1851 ,, 1872	22	0
May	18	1873 ,, 1891	19	0
June	16	1892 ,, 1905	14	0
July	14	1906 ,, 1918	13	0
August	14	1919 ,, 1927	9	3
September	13	1928 ,, 1949	22	0
October	10	1950 ,, 1961	12	0
November	13	1962 ,, 1979	18	0
December	6	1980 ,, 1985	6	0
Total	153	No. 1800 to No. 1985	186	3

The above, which is a continuation of former tables given in the *Monthly Notices*, has been but partially compiled from the photographs taken with the Kew heliograph.

Since these were discontinued in April last, their place has been supplied for the purpose of group numbering, on Schwabe's method, by rough sketches made from eye-observations with a refracting telescope of 3 inches apertures, using a power of 42.

There is a considerable falling off in the number of days of observation in 1872 as compared with 1871. This is accounted for in some measure by the greater prevalence of bad weather, but principally by the fact that during the chief part of the year, the observer not being exclusively engaged upon Sun-work, was unable to take advantage of temporary breaks in all clouds which offered themselves, the operation of mounting the telescope and making the drawing requiring more time than could always be spared from his other duties.

The system of eye-observation not having been decided upon until after the photographs ceased to be taken regularly, there is no comparative series between the two. There have, however, been several comparisons made at different times which tend to show the general accuracy of the sketches made by Mr. James Foster, one of the junior assistants at the Kew Observatory.

On an Apparatus for connecting the Hour Circle of the Equatoreal with the Regulator; and rendering audible the beat thereof. By Wentworth Erck, Esq.

The apparatus I am about to describe has now been in use on my own equatoreal for about a year, during which time it has been productive of so much comfort and convenience, that I have thought others might like to be made acquainted with it.

Its object is twofold,—

First, to keep the hour-circle constantly moving so as to show, at a fixed index, precisely the same time as that shown by the regulator.

Secondly, to render distinctly audible, even to deaf ears, the beats of the regulator.

Both these objects are effected by an electro-magnetic apparatus in which contacts are made by the vibration of the pendulum itself; whereupon the magnet attracts one end of a lever, the other end of which carries a pawl working in a ratched wheel on the axis of the endless screw that drives the hour-circle.

The hour-circle having 720 teeth, and the ratched wheel 120, if the latter receives an impulse every second, the former will revolve once in twenty-four hours; and this is what actually takes place.

The details of the mechanism by which this is effected are as follows: but I must premise that this circle is read in a very unusual way, though I venture to think a very much more convenient way than the usual one.

It is such a height from the floor, that by kneeling you can

see the whole of the southern surface of the circle unobstructed by the bearing of the polar axis.

For this axis projects some four inches beyond its southern bearing, the projecting portion being of gun-metal, cylindrical, and 1¼ inches in diameter; on this projecting portion of the axis, the hour-circle runs loose, its bearing also being 4 inches long, so as to impart steadiness to its movement.

The divisions are carried on a raised silver rim, about half an inch wide, projecting slightly below the southern surface of the circle, and affording space for a double set of divisions with a common set of figures between them.

The outer set of divisions are read off by a fixed vernier or index, in the meridian; and this index therefore, when the circle has been once set and kept in motion, always shows the clock time.

The inner set of divisions are read off by a pair of indices immovably fixed to the polar axis, and thus by mere inspection, without any calculation, show at once the apparent right ascension of any object to which the telescope may be directed; and, inasmuch as these indices and the hour-circle are relatively stationary, when the driving-clock is in gear, the right ascension can be read with ease and accuracy.

The reading-glasses are furnished with plain glass diagonal reflectors, and are carried round with the polar axis, so that they are always in position for reading; and by merely turning the reading-glass in its collar, you can perfectly illuminate the divisions at any hour-angle from a single fixed lamp.

The electro-magnetic apparatus, being of the very simplest form, scarcely requires description. The armature is at one end of a lever, at the other end of which is the pawl that works the ratched wheel; the arms of the lever being as 1 to 7.

The blows of the armature against the stops that prevents actual contact with the magnet, corresponding as they do with vibrations of the pendulum, rendered the latter most distinctly audible.

After many failures I succeeded in adapting to an existing clock a contact apparatus, which answers, I believe, as well as any thing of the kind can answer.

One of the battery wires is connected with the bracket which carries the pendulum; and the metallic communication is continued through the suspending spring into a small brass cube at the top of the pendulum rod. From opposite sides of this cube depend light springs, two inches long, having platinum terminals.

Screwed to the back of the clock-case, and connected with the other wire, is a small brass plate having two small pillars, 2 inches asunder, projecting forward; these pillars carry platinum-pointed screws in the plane of vibration, and opposite the terminals of the springs, so that, at each vibration, contact is made between a spring and a screw.

This interference with the pendulum has the effect of increas-

ing both the arc and the rate; the former to such a very small extent as to be immaterial; while the latter is under the control of the screw for adjusting the length of the pendulum.

But I suspect there is a constant, though very slow diminution of the corrected rate; whether due to the gradual consumption of the terminals, or to a gradual compression of imperfect springs, I am at present unable to say: but whatever owing to it is under control; you have only to advance the joints of the screws an exceedingly minute quantity.

The battery being only in action at the instant of contact there is not much consumption of materials. I find a single Daniell's cell exposing 3 square inches of zinc surface, and converting 15 grains into sulphate per hour, is quite sufficient to work the whole apparatus.

The battery is only put into operation when the equatoreal is in use; and at first I found some difficulty in having the battery always ready, at a moment's notice, at uncertain and long-separated intervals; also in keeping the fingers free from acid, &c. But these difficulties have been obviated by having the zinc plate of considerable length, and held in a kind of vice sliding on a rod, like a retort stand, which forms part of the circuit; thus the strength of the battery can be regulated, the same zinc will last a very long time, and there are no connexions to be made and unmade.

The porous pot, when not in use, is kept suspended by percha cords in a very large vessel of dilute acid, whence it can be filled, and emptied without touching it, the result of the whole matter being that in ten seconds I can without fail put the entire apparatus into working order.

Sherrington House, Bray, Co. Wicklow,
January 8, 1873.

Meteor observed at Mauritius.
By Mr. Wright.

(*Communicated by Mr. Meldrum, of the Mauritius Observatory.*)

On Thursday evening last, about 7 o'clock, I saw the most beautiful meteor fall that I ever remember observing in my life. My face was turned in the opposite direction, but an unusually brilliant and sudden flash of light, above the brightness of the moonshine, caused me to turn suddenly round in the direction the effulgence came from, and I saw a very large meteor majestically falling through the distance seemingly about 8 or 10 yards. I am not much of an astronomer, but I think it must have fallen (apparently) from some point in *Aquarius*. What particularly struck me in its appearance was, that it was beautifully distinct, and perfectly round as the full moon, but seemingly about the $\frac{1}{8}$th of a diameter larger. I ought, perhaps, rather to compare it to the moon at the end of her first quarter; for the lower quarter of

its disk only was luminous and brilliant, while the upper three quarters emitted no luminosity, being of a dull dusky stone-brown colour. Here the circular outline was perfectly distinct, while the brightness of the lower limb took away all distinctness of outline there, making it appear slightly more prominent, besides throwing beyond the outline of the meteor itself a beautiful soft, steady, very bright radiance of a bluish white tint, which illuminated momentarily the whole heavens. It was observed by other people; and one person described to me having seen a similar meteor fall about this time last year, the disk appearing about the size of a saucer, entirely luminous; but then no moon was shining.

A Fireball in Scotland. By H. D. Penny, Esq.

(*From a Letter to Mr. Dunkin.*)

Though I reported that we had thunder and lightning on Sabbath evening last, I had grave doubts as to the propriety of doing so, and since that time I have now reason to change my opinion.

I was coming up the street at half past 5 P.M. on that day, when without any warning I seemed enveloped in flame; on looking to the sky it seemed illuminated, and continued so for two or three seconds so brightly that I had no difficulty in seeing the smallest stone on the ground. For a second or so, the illumination waned, and then it shone for a second brighter than before. I hurried home to see the exact time of the circumstance, and being about 100 yards or so from the house, I heard when coming at the gate, a low rumbling noise as of distant thunder away to the south-west. I then concluded that it was thunder, and remained outside for half-an-hour in the expectation of hearing more, but in vain, as thunder is rather uncommon in this quarter at this season.

Though the sounds heard appeared like thunder, I could not reconcile the appearance of the illumination with a flash of lightning,—it remained so long visible. On making inquiries next day, I found that an uncommon meteor had been seen, and having learned that a person residing in the high lands about five miles to the south of this had been an eye-witness of it, I called upon him last night, and had the following particulars:—

On his way home from Nairn, and at the same hour as mentioned, he saw a large ball of fire, about the size of the full moon, coming up from the east-south-east, about twenty degrees from the horizon, and gliding along comparatively slowly, so that he could distinctly discern it. The ball was of the colour of intensely heated iron, and had a tail attached to it. For the two or three seconds it remained in sight the sky was so lighted up that he could have picked a pin from off the ground. It then seemed to him as if to descend behind some of the hills to the

south-west of him, and for a second the sky was darkened, when all at once the light burst forth stronger than before, and shortly afterwards he heard a sound as distinctly as if three or four cannon had been at once discharged, at a distance of a quarter of a mile. But the last lighting up of the sky seemed only for an instant, when all was dark as before.

With the exception of the person's seeing the meteor, I can corroborate his statement in every particular.

I have this morning seen a gentleman from Strathspey, a resident in Grantown. Like myself he saw the blaze of light and heard the sound shortly after, but the sound seemed to him to come from the north-west. My opinion is that there must have been a meteor of extraordinary size travelling from the southern part of Banffshire on towards the centre of Inverness-shire, and that it had burst somewhere near the source of the river Nairn. The brilliancy of the light was as if a vivid flash of lightning had remained visible in the sky.

Should I hear any further particulars of this unusual phenomenon, I shall take notes and communicate.

Nairn, 7th Nov. 1872.

Meteoric Showers of November 27, 1872. By Lieut. F. J. Gray, of the Surveying Ship "Nassau."

(*Communicated by Capt. Evans.*)

Knowing the great interest you take in any of the peculiar phenomena connected with the heavens, I have taken the liberty of sending you the following short account of an extraordinary meteoric shower seen here between 9 P.M. of the 27th and 3 A.M. of the 28th November.

About the former time a few meteors were first observed falling, the number steadily increasing until 11, when the maximum frequency was attained, and 308 counted in five minutes by two observers, one in each gangway, facing out-board; from this time until 3 A.M., the number decreased, ceasing altogether at that hour.

The majority were small and falling, but a few were excessively brilliant and shooting, leaving behind them a momentary luminous track of from 5 to 10 degrees in length, the advent of the larger ones being accompanied by a flash similar to that produced by the discharge of a distant gun.

All apparently came from near the zenith, the brightest entering the limit of vision at an altitude of about 60°, and, taking a direction towards that part of the horizon the observer was facing, disappeared at an altitude of about 35° or 40°; some of the officers that witnessed this appeared to think that the larger ones were lost near, or merged with, well-known stars of large magnitude, but this of course was purely imaginary.

The night was beautifully fine, atmosphere clear, and not a

cloud visible the whole time, in fact, everything favourable for observing this wonderful phenomenon.

Barometer at 11 P.M. $\frac{29{\cdot}88}{78{\cdot}5}$; temp. of air, 76·2; wind, N.E.N. 1 to 2, and a light dew falling.

Bombay, December 3, 1872.

Note on the Visibility of Jupiter. By William F. Denning, Esq.

(*Communicated by the Secretaries.*)

It is not generally understood that *Jupiter* is visible in sunshine to unassisted eyes of ordinary power, and I therefore communicate this note, bearing upon the subject, to the Society. I have made numerous naked-eye observations of this planet during the last two months, and find that he remains unmistakably visible until as nearly as possible thirty minutes after sunrise, when the limit of visibility is reached. I have seen *Jupiter* on several occasions when the Sun has been shining and quite free from cloud; but after the solar orb has attained an altitude of a few degrees the planet becomes imperceptible, being, in fact, entirely overpowered. I believe, however, that under favourable atmospheric conditions he is (when situated at a good elevation) within the range of acute vision at all times; unfortunately, though, our climate is unfavourable for such observations. I can very readily see *Venus* without instrumental aid at any period of the day when she is well placed for such a purpose.

Elements of the Minor Planet (118), *Peitho.*
By Professor Oppolzer.

(*Communicated in a letter from Dr. Luther to Mr. Hind.*)

The orbit is founded upon observations on March 15, 26, and April 4. Dr. Luther's first position is—

	M. T. Bilk.	R.A.	Decl.
March 15	$14^h\ 18^m\ 59{\cdot}6^s$	$12^h\ 7^m\ 26{\cdot}77^s$	$+1c^\circ\ 17'\ 25{\cdot}4''$.

Epoch 1872, March 31·0, Berlin M.T.

Mean Anomaly	$84^\circ\ 25'\ 12{\cdot}''3$	
π	76 28 32·4	Mean Equinox 1872·0.
Ω	47 14 25·5	
i	7 50 11·3	
φ	9 51 25·0	
μ	928″·402	
log a	0·388181	
Sidereal Period	1396 days.	

Note on the Total Solar Eclipse of 2151, *June* 14.

By Mr. Hind.

Having examined this eclipse (which has been indicated by the Rev. S. J. Johnson as likely to be total in London), using elements which represent with great precision the circumstances of the eclipses in the early part of the last century, I find the southern limit of totality will pass to the north of the metropolis. A line drawn across the map from Garstang in Lancashire to Lynn Regis, will nearly define the course of the central eclipse over this island. The eclipse is total in Sheffield for $2^m\ 38^s$, totality coming on at $6^h\ 10^m\ 56^s$ local mean time. In London the magnitude of the eclipse is 0·997, the greatest phase at $6^h\ 26^m$ p.m.; diameter of crescent 3″.

The eclipse of 2090, Sept. 23, will be total in Paris just before sunset; duration of totality, $2^m\ 27^s$.

I subjoin the elements of the eclipse of 2151, June 14, in case any one should wish to examine it further:

G.M.T. of Conjunction in R.A. 2151, June $14^d\ 5^h\ 15^m\ 40^s$.

		°	′	″
R.A.		82	53	12·8
Hor. Mot. in R.A.	☽		40	4·5
,,	☉		2	36·0
Declination	☽	+23	55	20·3
,,	☉	+23	15	30·6
Hor. Mot. in Decl.	☽	+	4	59·9
,,	☉	+	0	7·0
Hor. Parallax	☽		60	19·5
,,	☉			8·8
Semidiameter	☽		16	26·3
,,	☉		15	45·4

Equation of time $0^m\ 36^s{\cdot}0$ subtractive from Mean Time.

Sidereal Time at Greenwich noon $5^h\ 30^m\ 58^s{\cdot}8$.

ERRATA.

Page 102, line 13 from bottom, at the end of line, *insert* †.

— line 6 from bottom, *for* more, *read* none.